



Weather Impacts on the Aerostar Unmanned Aircraft System Based on Climatology over the U.S./Mexico Border

by Barbara Sauter

ARL-TR-4055

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White Sands Missile Range, NM 88002-5501

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Computational and Information Sciences Directorate

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14. ABSTRACT Unmanned Aircraft Systems (UASs) are becoming more prevalent performing both military and non-military functions. One potential function for a UAS is monitoring along the U.S./Mexico border. This report documents the percentage of time various weather parameters might be expected to degrade the performance of an Aerostar or similar UAS over the border regions based primarily on Advanced Climate Modeling and Environmental Simulations (ACMES) modeled climatology as well as other climatology data from the Air Force Combat Climatology Center (AFCCC). Many details are provided on the probability of Aerostar weather limitations being exceeded for specific border locations, months, and times of day. Similar inputs could be used in the future to run an automated decision aid to assist in long-term planning for effective use of particular UAS types, locations, and purposes.					
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Preface

Unmanned Aircraft Systems (UASs) are becoming more prevalent performing a variety of military and civilian functions. Sizes of UASs range from very small to quite large, but each type has weather conditions that limit or preclude its use. One potential mission for a UAS is to observe along the border between the United States and Mexico. This report examines the percentage of the time a particular UAS, the Aerostar, might be impacted by unfavorable weather conditions over this region. The Aerostar was chosen since it is currently being flown by the New Mexico State University, Physical Science Laboratory, Technical Analysis and Applications Center (TAAC) in the vicinity of Las Cruces, NM. The U.S. Army Research Laboratory (ARL) is investigating the development of an automated decision aid to provide guidance on weather impacts on the UAS based on a specific time and location for a mission. For longer-term planning, knowing the climatology of an area relative to the weather conditions impacting the UAS would allow mission planners to determine whether or not a particular UAS would be likely to be able to perform its mission the majority of the time. This report is a first attempt to describe the types and frequencies of weather conditions that could be expected to limit the operation of a UAS over the U.S./Mexico border. The method used was primarily visual inspections of climatology plots. In the future, a robust and flexible method is needed to digitally derive climatological impacts for different unmanned systems and different locations.

Acknowledgements

This report would not have been possible without the Web-based climatology data provided by the U.S. Air Force Combat Climatology Center (AFCCC). The author particularly acknowledges Mr. Mike Hunsucker and Dr. Scott Applequist at AFCCC for their prompt assistance in making upper air wind climatology data available and answering questions. The weather limitations of the Aerostar were provided by Dennis Zaklan, Unmanned Aerial Vehicles Operations Manager, Technical Analysis and Applications Center. The author also acknowledges helpful discussions related to this report from Robert Dumais, Jeffrey Passner, and David Sauter, all of the U.S. Army Research Laboratory.

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Summary

The operation of the Aerostar Unmanned Aircraft Systems (UASs) may be partially or completely degraded under certain weather conditions. Extremely low or high temperatures, the presence of clouds, high wind speeds, turbulence, icing, low visibility, fog, and rain may impact the UAS, depending on the aspect of a particular mission to be performed. This report compares the weather parameter thresholds expected to potentially impact the Aerostar functions with the percentage of time those thresholds are exceeded over the United States along its border with Mexico, based on climatology over the past 30 years.

The total percentage of time the climate can be considered unfavorable for Aerostar operations at locations along the U.S./Mexican border cannot be determined from this study, since the weather impacts from individual weather parameters are used without information on how many of those conditions overlap in time. Although some natural associations could be made, such as the percentage of time experiencing rain would be a subset of the percentage of time with clouds, the significant amount of unknown relationships made this overall analysis futile. In addition, it's possible that the weather threshold values used are less significant for some type of mission than other types, so a planner for a specific operation may want to focus on a particular subset of weather parameters.

The amount of modeled climatological data summarized in this study shows that sufficient data are available to run an automated UAS decision aid with climatology. When an exact location is known, additional climatology based on observations may be preferable, but many locations could, at least, be expected to have valuable information relevant to the area, whether or not a long-term record of observations is available.

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1. Introduction

Unmanned Aircraft Systems (UASs) are becoming more prevalent for both military and civilian functions, and U.S. Senator Domenici (Rep., NM) has stated a goal to expand their use over the U.S./Mexico border (1). Currently, the New Mexico State University, Physical Science Laboratory runs the Technical Analysis and Applications Center (TAAC), with the goal of promoting the safe use of UAS in civilian airspace for a variety of missions (2). The U.S. Army Research Laboratory (ARL) has provided weather forecast information to TAAC operators of an Aerostar UAS, in order to facilitate the development of an automated UAS decision aid. The initial implementation of the decision aid will provide information on potential weather impacts on a UAS for a specific time and place or route, based on a weather forecast model. Eventually, it would be desirable to generate decision aid output based on climatology for a region, in order to select optimum times or locations for UAS missions in the advance planning stage.

In the near term, with no automated climatological decision aid capability available, this study documents the types of modeled climatological data currently available from the Air Force Combat Climatology Center (AFCCC) relative to the data that would be needed to generate climatological weather impact information for the Aerostar. The AFCCC Web site is available for military users and other approved users with a login and password (3). Actual climatology based on historical observations for specific sites is also available from AFCCC, but in order to cover the border region, including surface and some upper air climatology, it was decided to rely on the climatology data based on model analyses, which provide more complete data over the regions and times of interest. Analyses of the percentage of time a weather threshold was exceeded were performed through visual inspections of the modeled climatology plots. These plots were generated for many weather parameters based on the month and time of day, when available.

2. Aerostar Weather Limitations

2.1 The Aerostar UAS

While UASs of other sizes and types may be operated for Homeland Security or other missions along the U.S./Mexico border, the Aerostar system was selected for this study since it is currently being flown in New Mexico and its weather limitation values are readily available. The Aerostar is 15 ft long and 4 ft high with a wingspan of 21 ft, and can be flown up to 18,000 ft mean sea level (MSL) for missions lasting up to 12 h (4). Figure 1 shows a photograph of an Aerostar at White Sands Missile Range, NM.



Figure 1. An Aerostar UAS with members of the support team at White Sands Missile Range, NM.

2.2 Weather Impacts on the Aerostar UAS

The appendix provides the manufacturer guidance on weather limitations pertaining to the Aerostar UAS. Categories of documented weather impacts on the functioning of the Aerostar include the following:

- Temperature
- Clouds
- Wind
- Turbulence
- Icing
- Visibility
- Fog
- Rain

Cold temperatures are primarily a concern in conjunction with humidity, which can result in icing. Hot temperatures affect the lift associated with atmospheric density and the fuel temperature for ignition. Clouds may lead to icing, turbulence, or restricted visibility for the UAS sensor. Strong winds, turbulence, and icing could all adversely affect the flight of the UAS. In addition, turbulence resulting in an error in the altitude can generate problems with the throttle. Fog or rain could hamper the visibility required for the sensor payload or for landing the UAS safely.

Threshold values of these weather parameters expected to impact the Aerostar are listed in table 1.

Table 1. Aerostar weather limitations.

Parameter	Aerostar Operating Limitation	Comments
Temperature	1–10 °C with RH >70%	The concern is potential icing.
Temperature	<1 °C	The concern is potential icing.
Temperature	>30 °C	High temperature may cause problems related to fuel ignition and landing.
Clouds	Any in flight path ^a	The adverse impact of clouds on the UAS may result from icing, turbulence, or low visibility.
Wind	Surface: day/night nose: 25/20 kts side: 15/10 kts tail: 2/2 kts	
Wind	Cruising altitude >40 kts ^a	
Turbulence	Presence of severe bumpiness ^a	
Icing	Presence of icing ^a	
Visibility	Low visibility	The only specific threshold mentioned is the ability of the operator to see the UAS at a slant path to an altitude of 1,000 ft on landing, but various payloads could also have different limitations based on restricted visibility.
Fog	Presence of fog	
Rain	Presence of rain	

NOTE: RH = relative humidity.

^a The Aerostar flight level is limited to up to 18,000 ft MSL.

3. Climatology Data

The AFCCC Web site (3) contains climatology information for many parameters and different locations. As mentioned in the introduction, this study relied primarily on climatology based on model output in order to view full coverage of the U.S./Mexico border. The intent was to investigate the frequency of occurrence of potentially limiting weather conditions for operating the Aerostar UAS. Therefore, the climatology categories used were restricted to those providing frequencies of occurrence, while maximum, minimum, and mean values were disregarded.

3.1 AFCCC Climatology Web Application

The majority of the climatology plots viewed for this study were obtained from the Advanced Climate Modeling and Environmental Simulations (ACMES) portion of the AFCCC Strategic Climatic Information Service Web site (3). These plots are available through either a Plot On Demand or an Images application, which may be obtained on the Web site by following the steps summarized below:

- *Plot On Demand*: Select Products, select Modeled Climatology, and then select Plot on Demand. Click on Launch ACMES Plot-on-Demand Application. For this study, the Continental U.S. (CONUS) region was selected, with a north latitude of 35°, a south latitude of 25°, a west longitude of -120° and an east longitude of -90°.
- *Images*: Select Products, select Modeled Climatology and then select Images. For this study, the U.S.-CONUS region was selected. The Images application plots the entire region selected without the ability to select a subset through entering desired latitude and longitude boundaries.

Another product used was the Real-Time Cloud Nephanalysis (RTNEPH), available as follows:

- *Real-Time Cloud Nephanalysis*: Select Products, and then select Real-Time Cloud Nephanalysis. Click on Launch RTNEPH Web Application. For this study, the radio button for Select by Coordinate Boundaries was chosen, with a northern extent of 37° N, a southern extent of 22° N, a western extent of 120° W, and an eastern extent of 90° W.

Finally, in order to provide supplemental information related to icing and thunderstorms, Climatological (Climo) Atlases were accessed as follows:

- *Climo Atlases*: Select Products, select Maps, select Climatological Atlases, and then select the radio button for the desired climatology atlas; height, if applicable; and month. Finally, click on the Refresh Map button above the map.

The only parameter included in this study that is not routinely available through the Web application was flight level wind information, which was provided on request. The other parameters were all available on a monthly basis, and all parameters except potential icing conditions were available by hour or every three hours for each month. The Flight Level Winds data existed for the hours of 0000 Zulu (00Z) and 1200 Zulu (12Z) only, for each month. The products are based on a ten-year period of record.

3.2 Climatology Parameters

Climatological parameters were not always available to match exactly with the Aerostar weather limitation thresholds, but sufficient parameters were readily accessible to reasonably cover the desired data. Table 2 lists the parameters available from ACMES, table 3 lists the parameters available from RTNEPH, and table 4 lists the parameter choices from Climo Atlases, with the parameters and levels used for this study highlighted in boxes within each table.

Table 2. ACME parameter choices.

ACMES		Available		Available in	
Main Parameter	Subparameter	each month	each hour	Plot on Demand	Images
Temperature	Freq 2 m Temperature < 0.0	X	X	√	√
	Freq 2 m Temperature < 32.0	X	X	√	√
	Freq 2 m Temperature > 90.0	X	X	√	√
	Max 2m MaxDaily Temperature	X		√	√
	Mean 2m Max Daily Temperature	X		√	√
	Mean 2m Min Daily Temperature	X		√	√
	Mean 2m Temperature	X	X	√	√
	Min 2m Min Daily Temperature	X		√	√
Dew Point	Max Lev1 Dew Point	X	X		√
	Mean Lev1 Dew Point	X	X	√	√
	Mean Lev1 Max Daily Dew Point	X			√
	Mean Lev1 Min Daily Dew Point	X			√
	Min Lev1 Dew Point	X	X		√
Humidity	Max Lev1 RH	X	X		√
	Mean Lev1 Max Daily RH	X		√	√
	Mean Lev1 Min Daily RH	X		√	√
	Mean Lev1 RH	X	X		√
	Mean Lev1 Spec Humidity	X	X		√
	Min Lev1 RH	X	X		√
Precipitation	Freq Daily Precip > 0.01	X		√	√
	Freq Daily Precip > 0.40	X		√	√
	Freq Hourly Precip > 0.00	X	X	√	√
	Max Hourly Precip	X	X		√
	Max Monthly Precip	X		√	√
	Mean Hourly Precip	X	X		√
	Mean Monthly Precip	X		√	√
	Min Monthly Precip	X			√
Snow	Freq Blowing Snow event	X	X		√
	Freq Hourly Snowfall > 0.00	X	X	√	√
	Freq Snow on Ground > 0.10	X	X		√
	Max Daily Snowfall	X		√	√
	Max Hourly Snowfall	X	X		√
	Max Monthly Snowfall	X		√	√
	Max Snow on Ground	X	X		√
	Mean Monthly Snowfall	X		√	√
	Mean Snow on Ground	X	X		√
	Min Monthly Snowfall	X			√
Pressure	Min Snow on Ground	X	X		√
	Max Altimeter Setting	X	X		√
	Mean Altimeter Setting	X	X		√
	Mean Density Altitude	X	X		√
	Mean Pressure Altitude	X	X	√	√
	Min Altimeter Setting	X	X		√

NOTE: Selected parameters are highlighted in boxes.

Table 2. ACME parameter choices (continued).

ACMES		Available		Available in	
Main Parameter	Subparameter	each month	each hour	Plot on Demand	Images
Wind	10m Prev. Wind Speed	X		√	√
	Freq Lev1 Wind Gust > 25.0	X	X	√	√
	Freq Lev1 Wind Gust > 35.0	X	X		√
	Freq Lev1 Wind Gust > 50.0	X	X		√
	Max 10m Wind Speed	X	X		√
	Max Lev1 Wind Gust	X	X	√	√
	Mean 10m Wind Speed	X	X	√	√
Weather	Freq Fog event	X	X	√	√
	Freq Freezing Rain event	X	X		√
	Freq Haze event	X	X		√
	Freq Ice Pellets event	X	X		√
	Freq Obstructed Vis event	X	X		√
	Freq Thunderstorms event	X	X	√	√
Turbulence	Freq High Turb {10-50 kft} >=1	X	X		√
	Freq High Turb {10-50 kft} >=2	X	X		√
	Freq High Turb {10-50 kft} >=3	X	X		√
	Freq Low Turb {1-6 kft} >=1	X	X		√
	Freq Low Turb {1-6 kft} >=2	X	X		√
	Freq Low Turb {1-6 kft} >=3	X	X		√
	Freq Mid Turb {6-10 kft} >=1	X	X		√
	Freq Mid Turb {6-10 kft} >=2	X	X		√
	Freq Mid Turb {6-10 kft} >=3	X	X		√
Icing	Freq High Icing {10-30 kft} >=1	X	X		√
	Freq High Icing {10-30 kft} >=2	X	X		√
	Freq High Icing {10-30 kft} >=3	X	X		√
	Freq Low Icing {1-6 kft} >=1	X	X		√
	Freq Low Icing {1-6 kft} >=2	X	X		√
	Freq Low Icing {1-6 kft} >=3	X	X		√
	Freq Mid Icing {6-10 kft} >=1	X	X		√
	Freq Mid Icing {6-10 kft} >=2	X	X		√
	Freq Mid Icing {6-10 kft} >=3	X	X		√
Clouds	Freq Cloud Top < 10.0	X	X		√
	Freq Cloud Top < 20.0	X	X		√
	Freq Cloud Top < 30.0	X	X		√
	Freq Cloud Top < 40.0	X	X		√
	Mean Int Cloud Cover	X	X		√
Cig/Vis	Freq Ceiling > 0.0	X	X	√	
	Freq Cig/Vis < 1.0kft/2.0mi	X	X	√	
	Freq Cig/Vis < 1.5kft/3.0mi	X	X	√	
	Freq Cig/Vis < 3.0kft/3.0mi	X	X	√	
Flt Lev Wind	Freq {5/10/12/15/18} K ft msl > 35		00 & 12Z		experimental
	Freq {5/10/12/15/18} K ft msl > 50		00 & 12Z		experimental

NOTE: Selected parameters are highlighted in boxes.

Table 3. RTNEPH parameter choices.

RTNEPH		Available	
		each month	each 3rd hour
Parameter	Level (ft)		
Mean Total Cloud Amount [%]		X	X
StdDev Total Cloud Amount [%]		X	X
Freq Cloud Type Clear [%]		X	X
Freq Cloud Type Cb [%]		X	X
same as above for St, Sc, Cu, As, Ns, Ac, Cs, Cc, Ci		X	X
Freq Cloud Type Fog [%]		X	X
Freq Cloud Type Unknown [%]		X	X
Freq SKC [%]		X	X
same as above for FEW, SCT, BKN, OVC		X	X
Freq MCF 0-10%		X	X
same as above for 11-20, ..., 91-100		X	X
Freq of any Ceiling [%]		X	X
Freq CIG at or below [selected level] [%]	500	X	X
	1000	X	X
	1500	X	X
	3000	X	X
	5000	X	X
	10000	X	X
	15000	X	X
	20000	X	X
	30000	X	X
	50000	X	X
	70000	X	X
Mean Cld Cvr at or below [selected level][%]	same as above	X	X
Cloud Cover Looking Up from [selected level][%]	same as above	X	X
Cloud Cover Looking Down from [selected level][%]	same as above	X	X

NOTE: Selected parameters are highlighted in boxes.

Table 4. Climo Atlases parameter choices.

CLIMO ATLASES		Available	
Parameter	Level (ft)	each month	each xxx hour
Cloud Ceiling [%]	[9 choices]	X	6th
Ceiling/Visibility [%]	[8 choices]	X	3rd
Thunderstorm [%]		X	3rd
Potential Icing [%]	0-1000	X	
	1000-3000	X	
	3000-5000	X	
	5000-7000	X	
	7000-9000	X	
	8000-12000	X	
	12000-16000	X	
	16000-20000	X	
	20000-24000	X	
	24000-28000	X	
	28000-32000	X	

NOTE: Selected parameters are highlighted in boxes.

4. Methodology

As previously mentioned, the methodology used for this study was manually intensive, relying on visual inspection of plots of the frequency of occurrence of the selected parameters and thresholds expected to impact the operation of the Aerostar. These inspections were performed for plots on an hourly basis for each month, with the exception of every three hours for the cloud analysis and the Thunderstorm Frequency Climo Atlas. Other exceptions were daily precipitation, which, of course, does not have an hourly component; and flight level winds, which were only available at 00Z and 12Z. All the parameters, except flight level winds, were also plotted to show frequency values over each month for all the available times combined. An example of an ACMES Plot on Demand chart is shown in figure 2. The RTNEPH cloud plots are similar, except the charts cover a slightly larger area in latitude. The ACMES Image charts depicting the entire CONUS are shown in figure 3.

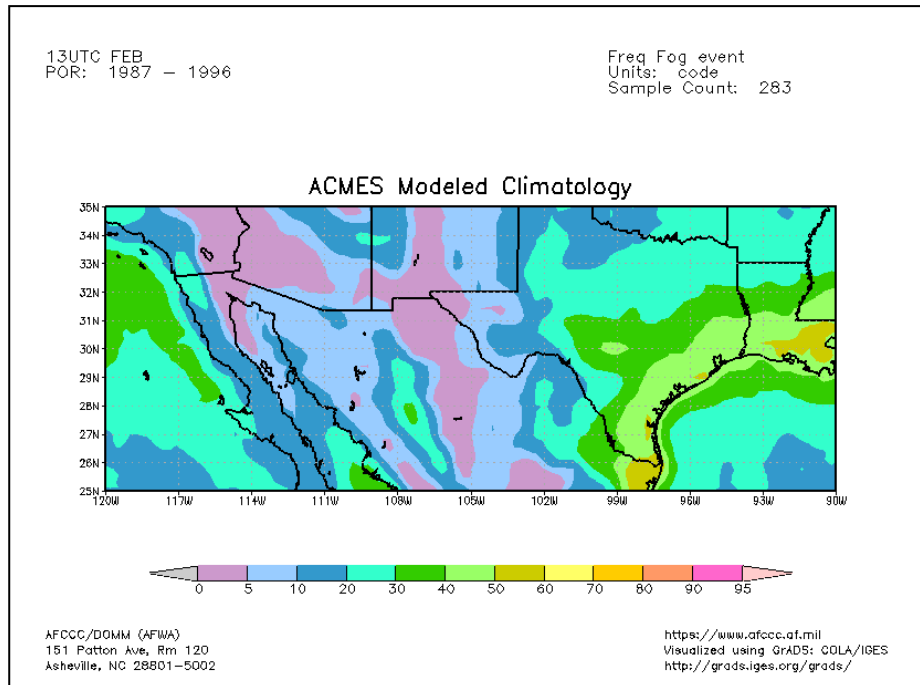


Figure 2. A sample ACMES Plot on Demand modeled climatology plot, with frequencies shown in percentages.

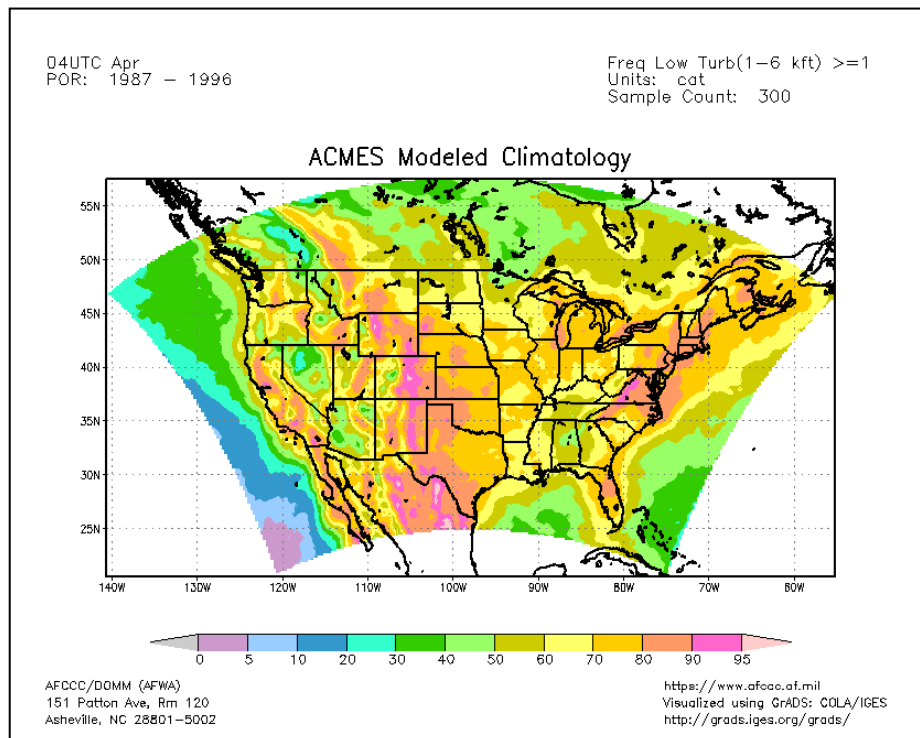


Figure 3. A sample ACMES Image climatology plot, with frequencies shown in percentages.

Although the plots depict more area, the analyses were limited to regions in the United States within approximately 100 mi from the border with Mexico, as shown in the shaded region in figure 4.

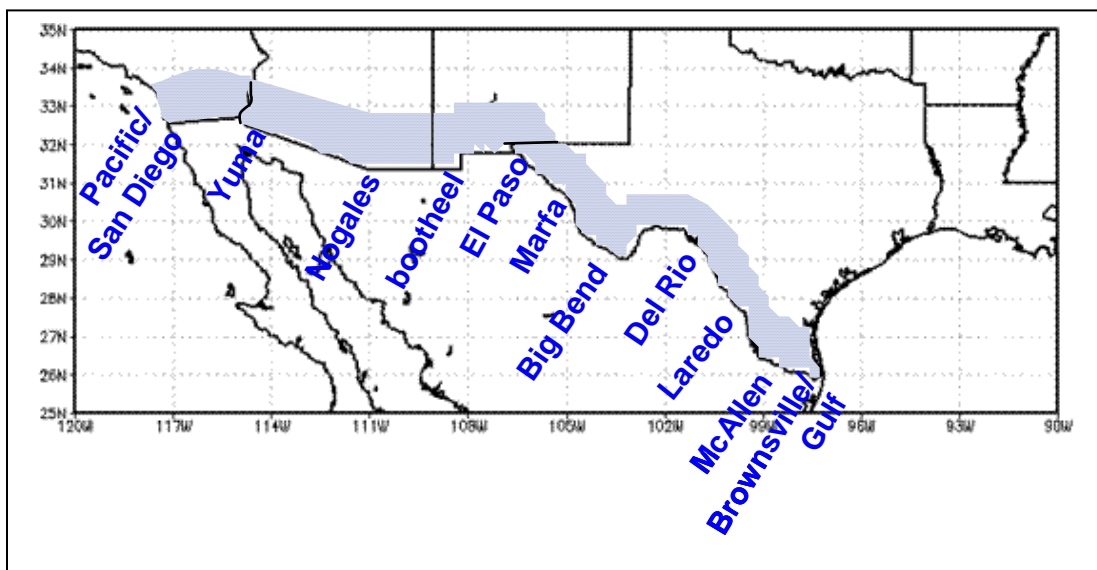


Figure 4. The border region included in this study, shown in the shaded area.

The results of these numerous plots are described in the following section, with discussions focusing on the expected frequency of weather impacts on the Aerostar UAS along the U.S./Mexico border by each parameter, including some details relating to the individual parameter frequencies by time of day, month, and region.

5. Results

5.1 Temperature Impacts

5.1.1 Cold Temperatures

The potential impact on the Aerostar UAS from cold temperatures is based on problems related to icing. The documented thresholds for Aerostar operating limitations include 1–10 °C with relative humidity greater than 70%, or temperature below 1 °C. Both surface and upper air temperatures up to the UAS top operating altitude of 18,000 ft MSL would be a concern. These thresholds are provided for the Aerostar operators to be aware of the possibility of icing when the temperature forecast or observation falls within the specified ranges. However, since this climatological study already has access to the frequency of icing, this temperature parameter threshold might reasonably be omitted, and the lack of upper air temperature climatologies is not considered a significant gap. Since the data for surface temperature values below 32 °F are readily available, the analysis for frequencies of freezing surface temperatures is provided.

Surface temperatures below 32 °F occur 0–5% of the time for the entire region under consideration between April and October. The lower elevations in California, western Arizona, and central and eastern Texas remain under 5% for the winter months as well. Frequencies greater than 5% are highlighted below:

- Cold temperatures are most frequent in higher elevations of New Mexico and west Texas, along with the bootheel of New Mexico, extending to the mountains east of San Diego, CA; southeastern Arizona; all of southern New Mexico; and western Texas in the coldest times.
- December and January experience the most frequent temperatures below freezing, with occurrences greater than 5% of the time in the evening through the morning in the coldest areas. November, February, and March experience freezing temperatures primarily during the nighttime hours.
- The areas most affected by freezing temperatures still generally only experience them 10–20% of the time in November and February, increasing to 20–30% of the time during the night and early morning hours in December and January. The exceptions are the mountains in New Mexico within 100 mi of the border, which experience freezing temperatures 30–70% of the time depending on the elevation.

5.1.2 Hot Temperatures

Hot temperatures may cause problems related to fuel ignition and landing. Density altitude is not explicitly listed in the Aerostar weather limitations document, but may be another significant limitation affected by high temperatures (5). The threshold given as the Aerostar limitation is any temperature greater than 30 °C. Since these impacts are surface based, and since the hottest temperatures would generally be found at the surface, upper air temperature climatology is not required. The readily available climatology data based on the frequency of surface temperatures greater than 90 °F was considered a close approximation of 30 °C.

Not surprisingly, temperatures exceeding 90 °F are very common along the U.S./Mexico border region. As shown in figure 5, the occurrence of these high temperatures can vary greatly over small distances, based on the proximity to a coastline or elevation differences. The basic pattern displayed in the figure is generally typical, with frequency maximums centered near Yuma, AZ, and Laredo, TX; and minimums hugging the coastlines and over the higher terrain of southeastern Arizona and the bootheel of New Mexico, along with a local minimum in the vicinity of Marfa, TX.

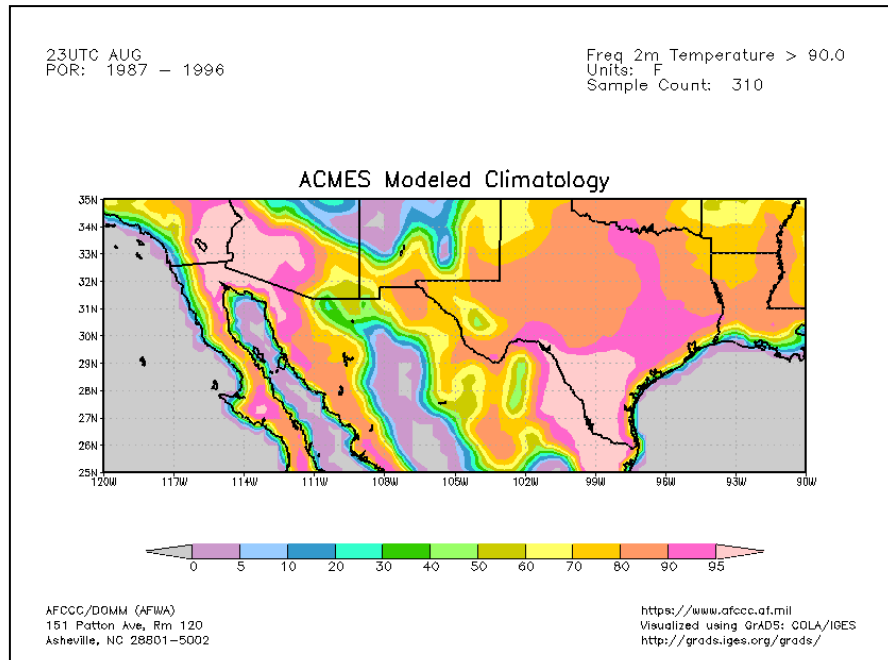


Figure 5. A typical climatology pattern highlighting the frequency percentages of surface temperatures exceeding 90 °F at locations along the border.

The wide variability in the percent occurrence of temperatures above 90 °F makes summarizing the data concisely impossible, but some noteworthy observations are provided below:

- The threshold for high temperature is not exceeded more than 5% of the time for all hours combined for October through March anywhere in the study region, but there are specific times and regions in late fall and early spring where 90 °F temperatures are not that rare. Specifically, the maximum amount of time the threshold is exceeded at approximately 4 p.m. local time reaches up to the following:
 - ✓ 40–50% near Laredo, TX, and 50–60% in eastern California and western Arizona in October
 - ✓ 10–20% near Laredo, TX, in November
 - ✓ 20–30% between Laredo and McAllen, TX, and 10–20% near Yuma, AZ in the mid-afternoon in March
- In April and May, no area exceeds the threshold more than about 10% of the time for the individual overnight and early morning hours, 11 p.m. through 10 a.m. The stretch between Big Bend, TX, and central Arizona does not exceed the threshold more than 10% of the time at any hour in April, while the entire Texas border region, other than right along the Gulf coast, exceeds the threshold at least 50% of the time during the hottest hours of the afternoon in May. Maximum values at around 4 p.m. in May include the following:

- ✓ 90–95% Laredo to McAllen, TX; 80–90% over adjacent areas; 60–80% at Big Bend, TX; and 30–50% at El Paso, TX
- ✓ 5–20% over southeastern Arizona and southwestern New Mexico
- ✓ 50–60% at Yuma, AZ, decreasing quickly westward to 10–20% at central California, and less than 5% along the Pacific coast
- For the hottest spots near Laredo, TX, and Yuma, AZ, by July the only hours that have a negligible chance of remaining below 90 °F are around 6–7 a.m., while southeastern Arizona can be expected to remain below that threshold value between about 9–10 a.m. During the heat of the afternoon in July, everywhere in the border region in this study, outside the immediate coastal areas, experiences temperatures greater than 90 °F over half the time. The worst times for operating an Aerostar based on hot temperatures are in July, as described below:
 - ✓ Starting at 11 a.m. at Brownsville, TX, and then extending westward over the next couple of hours up the Texas coast to Del Rio, the threshold can be expected to be exceeded 90–100% of the time, lasting until 8 p.m.
 - ✓ Between 2 and 5 p.m., the threshold normally is exceeded 60–80% of the time over southeastern Arizona and southwestern New Mexico.
 - ✓ From noon to 6 p.m. the region from central California to central Arizona experiences 90 °F or hotter 90–100% of the time.
- August remains similar to July in terms of hot weather impacts, except the regional extent and time duration of the hottest temperatures are smaller.
- By September, hot temperatures are no longer a concern during the morning hours between approximately 5–10 a.m. The most frequent occurrences of temperatures above 90 °F in September are likely to occur at 5 p.m. and in the following areas:
 - ✓ 90–95% at McAllen, TX, and 60–70% westward to Big Bend, TX
 - ✓ 40–50% over central New Mexico, decreasing to a maximum of 20–30% over southeastern Arizona
 - ✓ 90–100% between central California and central Arizona, but decreasing rapidly both to the west and to the east

5.2 Cloud Impacts

The existence of clouds in the Aerostar flight path may lead to a variety of problems, including icing, turbulence, and low visibility. The following discussion on the frequency of clouds over the U.S./Mexico border region is limited to the frequency that a cloud ceiling exists, meaning the sky at the observation location is at least five-eighths covered by clouds. In addition to

considering how often a ceiling exists at or below 15,000 ft MSL, some emphasis is also placed on the existence of clouds at a lower level, relevant to UAS missions restricted to lower altitudes. These lower cloud frequencies are based on being at or below 5,000 ft MSL for lower terrain, or being at or below 10,000 ft MSL for areas at higher elevations, including central California and Nogales, AZ, eastward to Del Rio, TX. Figure 6 shows a sample chart of the February 1800 Zulu (18Z) frequencies of cloud ceilings at or below 15,000 ft MSL.

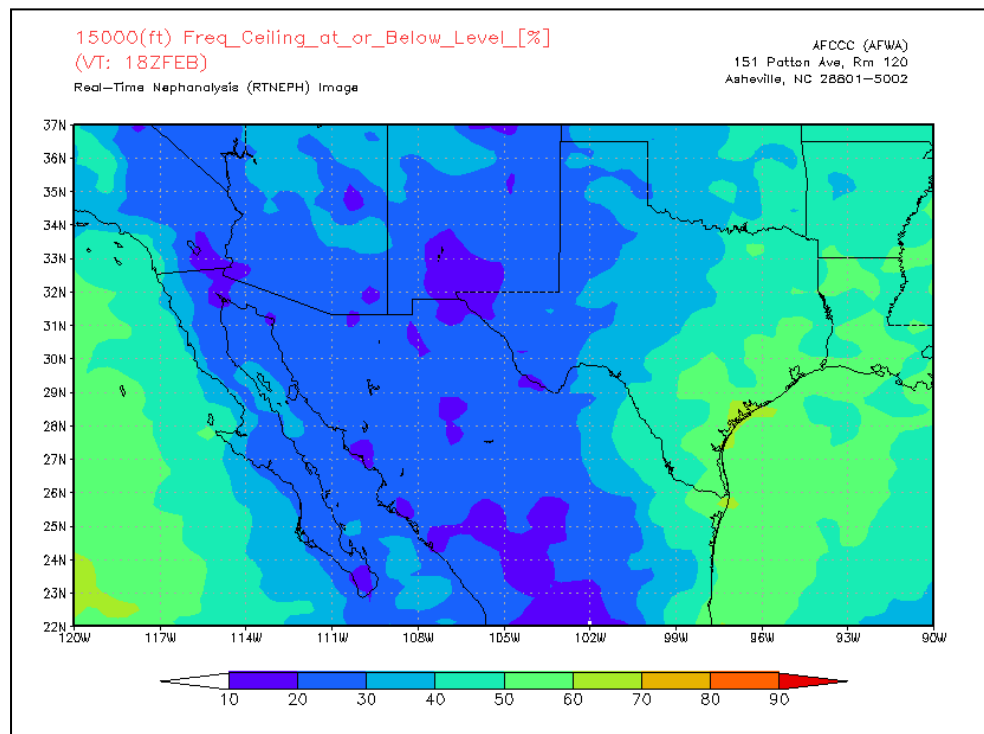


Figure 6. A sample chart of cloud ceiling frequency percentages at or below 15,000 ft MSL for February at 18Z.

A cloud ceiling is present approximately 20% of the time over much of the U.S./Mexico border region, with the exceptions of higher average values over eastern Texas and reaching approximately 40% along both the Pacific and Gulf of Mexico coasts. Variations in cloud cover between the coastal and inland regions are more significant than variations between months or times of day, although some strong seasonal or diurnal affects are detailed below. Considering only the lower altitude limit (5,000 or 10,000 ft MSL) generally produces cloud ceiling frequencies at least 50% and often close to 100% of those seen when including up to 15,000 ft MSL, so most of the cloud ceilings are not solely in the upper regions of the Aerostar's potential operating altitude. Additional results are noted below:

- The most common pattern is similar to that seen in figure 6, with the highest frequency of clouds over the coast of the Gulf of Mexico, decreasing westward to the Del Rio area of Texas, with another lesser maximum along the Pacific coast and minimums over the Yuma and El Paso areas in Texas. Exceptions include the following:

- ✓ During the summer months, the Pacific coast area experiences more clouds than the eastern Texas/Gulf of Mexico region.
- ✓ During the summer months, another area of increased cloudiness occurs over eastern Arizona and western New Mexico, with cloud ceiling frequencies of 30–50%.
- A predominant diurnal effect is seen in the highest percentage of cloud ceilings of up to 80% in the morning hours along the Pacific coast in the summer months, compared to 30% in the afternoon. The Gulf coast also experiences more clouds in the morning than in the afternoon hours during the summer, but the maximum frequency of cloud cover is less at 60%.
- Seasonal variations include minimum frequencies of cloud ceilings 0–20% of the time during May, June, and October for the regions from central California eastward through Big Bend, TX. Most of these regions experience their highest percentage of cloud ceilings in January at 20–40%, although as previously mentioned eastern Arizona and western New Mexico have somewhat higher percentages during the summer, particularly during the evening hours in July and August.
- The rest of the Texas coast from the Gulf of Mexico to Del Rio experiences its minimum amount of cloud ceilings typically less than 20% during the evening and night hours in July and August.

5.3 Wind Impacts

5.3.1 Surface Level Winds

The potential problems for the Aerostar based on surface wind speeds are tied to the wind direction relative to the take-off and landing directions, and are more restrictive during the night, as shown in table 5.

Table 5. Surface wind speed thresholds based on orientation and time.

	Day	Night
Headwind (kts)	25	20
Crosswind (kts)	15	10
Tailwind (kts)	2	2

It is frequently possible to adjust the direction of takeoff to preclude direct headwind or tailwind situations. The existence of moderate crosswinds seems to be a more prevalent concern. The readily available climatology threshold of frequency of surface wind gusts greater than 25 kts should be correlated to the sustained crosswind threshold of 15 kts, even though it may

underestimate the percentage of time that wind speeds actually exist from any direction at 15 kts or greater. Climatologies for specific wind directions and speeds are available for multiple points, and should be considered when a single location is under consideration with a known runway configuration.

The only U.S./Mexico border locations and times that experience wind gusts greater than 25 kts more than 5% of the time for all times in a particular month are the San Diego, CA, coast area in November, December, and January; and western New Mexico and the El Paso, TX, region in March. The maximum percentage of wind gusts exceeding 25 kts at any particular location and hour is only up to 20%. The months least likely to produce strong wind gusts are any time of day in September and October, during the evening hours November through January, the evening and night times in February through May, any time except the late afternoon or evening in June and July, and any time except the late afternoon in August. Strong wind gusts are very uncommon in the regions from eastern California to central Arizona and from Big Bend to Del Rio, TX. Areas with wind gusts over 25 kts occurring 5–20% of the time are detailed below:

- Wind gusts are most prevalent over the Pacific coast near San Diego, CA, during the winter months, but still only exceed 25 kts up to 20% of the time during the morning hours and up to 10% of the time during the afternoon and overnight in November through January, and up to 10% of the morning hours in February.
- Moving inland to the central portion of California's border with Mexico, winds become gustier over the spring and summer months than those seen along the coast. Wind gusts greater than 25 kts occur up to 20% of the time during the early evening hours and up to 10% of the time in the afternoon and late evening hours in May and June. They also occur up to 10% of the time in the afternoon hours from December through July, beginning in the morning hours in January through March and shifting later in the day and extending into the evening in April through July.
- Southeastern Arizona experiences wind gusts in excess of 25 kts up to 10% of the time during the late morning and afternoon hours in November.
- Strong wind gusts are most common over the New Mexico and far west Texas border regions during the spring, but also exist in the winter months. The New Mexico bootheel experiences wind gusts greater than 25 kts up to 20% of the time during the afternoon hours in November, while all of the New Mexico and El Paso to Marfa, TX, border regions may experience this amount of wind gusts during the afternoon hours February through May. These areas are also likely to encounter wind gusts greater than 25 kts up to 10% of the time during the afternoon in November through January, and during the late morning and early evening hours February through May.

On the other hand, the area around McAllen, TX, is more likely to have wind gusts greater than 25 kts up to 10% of the time during the afternoon and early evening hours from May through August. These strong gusts extend to the Gulf coast only in the afternoon hours in May, and extend westward to Laredo, TX, in the late afternoon or early evening hours in June and July.

5.3.2 Upper Air Level Winds

The maximum wind speed suitable for Aerostar operations at cruising altitudes is 40 kts, with the maximum cruising altitude capped at 18,000 ft MSL. The upper air wind climatologies are not currently available through the AFCCC Web site (3). However, upon request sufficient information was made temporarily available for this study. The specific parameters reviewed are detailed in table 6. Although only two times were available, the upper air wind speeds do not exhibit as strong of a diurnal change as the surface winds, so these times should adequately represent the upper air wind speeds to be expected.

Table 6. Upper air wind climatology parameters used.

Thresholds (kts)	Times (Z)	Months	Altitudes (ft MSL)
>35 >50	00 12	all	5,000 10,000 12,000 15,000 18,000

The 5,000 ft MSL data would be only 1,000 ft or less above the surface level for the highest elevation in California and for much of the high desert in eastern Arizona, New Mexico, and western Texas. Numerous peaks in those regions are above 5,000 ft, with some approaching the 10,000 ft level. The general terrain elevations of the border area are depicted in figure 7.

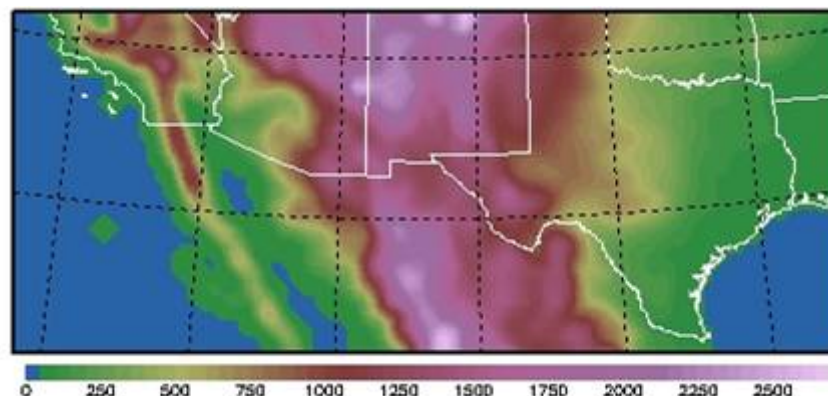


Figure 7. Terrain elevation in meters.

As already mentioned, the time of day is not a significant factor in the percentage of time upper air wind speeds exceeded the thresholds of 35 or 50 kts. The 00Z data usually reflect similar or slightly less frequent high wind occurrences than the 12Z data. It seems counterintuitive that wind speeds would be even slightly higher in the morning hours than in the afternoon hours, and no explanation is seen for this other than a possible bias in the modeled climatology data. Much more significant are the influences of season and height, which behave as expected with more frequent high wind speeds in the winter and at higher altitudes. Upper air winds greater than 35 kts occur 0–5% of the time below 18,000 ft MSL during July and August, with only limited areas experiencing those winds up to 20% of the time in June, September, and October. During the winter months, some areas experience winds greater than 35 kts at 12,000 ft MSL 20–30% of the time and at 18,000 ft MSL up to 60% of the time. The 50-kts threshold is also exceeded in some places 10–30% of the time at 15,000 and 18,000 ft MSL during the winter. Some specific upper air wind speed results by area are provided below:

- Although near sea level, upper air wind speeds are not a problem in the San Diego, CA, area at 5,000 ft MSL; however, they can be expected to exceed 35 kts at 10,000 ft MSL 5–10% of the time in April and May, and 10–20% of the time in December through March. These values generally increase another 10% at 12,000 ft MSL, reaching 30–40% at 15,000 ft MSL and 40–50% at 18,000 ft MSL in January through March. The increase with altitude is not prevalent in the fall and late spring months, when the wind speed remains greater than 35 kts 10–30% of the time at the levels above 12,000 ft MSL.
- The central and eastern California border regions do exceed the 35-kts wind speed at 5,000 ft MSL and 10,000 ft MSL 5–10% of the time during the winter months, increasing to 10–20% of the time at 12,000 ft MSL November through March. The wind speeds at 15,000 ft MSL and 18,000 ft MSL are similar to the San Diego area winds.
- Of the Arizona border regions, the area around Nogales tends to experience upper air wind speeds greater than 35 kts most frequently, with the Yuma area least likely to experience those winds. At 5,000 ft MSL, Nogales can expect these winds 5–10% of the time during November through January. At 10,000 ft MSL, most of central and eastern Arizona, and to a lesser extent the Yuma area, will have this level of winds November through March. The 5–10% frequency extends to October and April and May at 12,000 ft. MSL, while at this height the frequency increases to predominantly 10–20% for all the Arizona border regions from November through May, with the Nogales area reaching 20–30% in February. At 15,000 ft MSL, wind speeds greater than 35 kts occur over western Arizona 5–10% of the time in October and June; 10–20% in April and May; 20–30% of the time in November, December and March; and 30–40% in January and February. Eastern Arizona is the same as western Arizona at 15,000 ft MSL except for less frequent high winds in June, and more frequent at 30–40% in November and December. Going up to 18,000 ft MSL typically increases the frequencies by 10%, with additional impacts up to 10% of the time seen over western Arizona in September.

- For New Mexico and west Texas to the Big Bend area, the most common frequencies of wind speeds exceeding 35 kts are 10–20% at 10,000 ft MSL November through March. This frequency persists for most areas at 12,000 ft MSL during November and March, but also extends into October and April. It increases to 20–30% for most of the area December through February, as well as for the western Texas areas in March. At 15,000 ft MSL, the months of November through March experience these winds 30–40% of the time, decreasing to 20–30% in April and 10–20% in October and May. At 18,000 ft MSL, these areas can expect these strong winds 40–60% of the time during November through March, often with a somewhat lower likelihood over the western New Mexico region than over the El Paso to Big Bend areas in Texas. The frequencies decrease to 30–40% in April, 10–30% in May, 5–10% in June, and 10–20% in October, except 5–10% over the Big Bend area in October.
- In the central Texas vicinity including the Del Rio and Laredo regions, the only impacts greater than 5% of the time at 5,000 ft MSL are wind speeds greater than 35 kts 5–10% of the time at Del Rio in November, and at Laredo March through May. The 5–10% frequency remains at 10,000 ft MSL for the area around Del Rio in November, extending over both regions in December through February. On the other hand, while Del Rio experiences this 5–10% frequency in March, the Laredo area that had higher winds at the lower elevation does not experience them as often at 10,000 ft MSL in March or April. At 12,000 ft MSL, these areas experience wind speeds greater than 35 kts 5–10% of the time in November and April, and predominantly 10–20% of the time in December through March, although somewhat higher at 20–30% at Del Rio in January and at Laredo in March. These strong winds exist consistently 30–40% of the time at 15,000 ft MSL in December through March, decreasing to 10–20% in November and April and 5–10% in May, although the Del Rio area has somewhat higher frequencies in November and May than seen around Laredo. At 18,000 ft MSL the maximum frequency reaches 50–60% of the time during January through March, with lower occurrences 40–50% of the time in December, 20–40% of the time in November and April, and 5–10% of the time in May. During the fall and spring months, the Del Rio region is more likely to be at the high end of the frequency range than the area around Laredo.
- For the easternmost stretch of the U.S./Mexico border from approximately McAllen, TX, to the Gulf of Mexico, the only months experiencing winds greater than 35 kts at 5,000 ft MSL more than 5% of the time are March through May. Similarly to the other regions showing limited impacts at this level, the frequency does not exceed 10%. As described for the Laredo area, these impacts may be somewhat less frequent at 10,000 ft MSL during the spring than they appear at 5,000 ft MSL, while they are more frequent during January and February, but only at 5–10% of the time. The frequencies increase at 12,000 ft MSL to 5–10% in December and 10–20% during January through March. However, they remain lower at 12,000 ft MSL than the frequencies seen at 5,000 ft MSL during April and May.

This region generally experiences fewer high wind episodes at 15,000 ft MSL than the other places along the U.S./Mexico border. The maximum frequencies at this altitude are 5–10% in May and November, 10–20% in December and April, and predominantly 20–30% in January through March. At 18,000 ft MSL, the frequencies are 5–10% in May, 10–20% in November, 20–30% in April, 30–40% in December, and 40–50% in January through March.

None of the U.S./Mexico border region experiences upper air wind speeds greater than 50 kts more than 5% of the time below 12,000 ft MSL. The only areas with winds that strong at 12,000 ft MSL 5–10% of the time include the New Mexico and El Paso regions in November through January. The entire border region can expect winds exceeding 50 kts at 15,000 ft MSL at least 5–10% of the time in January, continuing everywhere in November through March, except over eastern Texas. The San Diego area in California is most likely to have these winds continue in April and May, along with central Arizona through El Paso, TX, in April. The highest frequency of wind speeds greater than 50 kts at 15,000 ft MSL is 10–20% of the time, which is most likely to occur in the San Diego region as well as central Arizona through west Texas in November through March. At the maximum altitude of 18,000 ft MSL, winds exceed 50 kts over the entire U.S./Mexico border region at least 10–20% of the time from January through March. This frequency extends to November and December for all areas except eastern Texas, with somewhat less frequent high winds in April and May but still over 5%. The areas experiencing winds greater than 50 kts 20–30% of the time at 18,000 ft MSL include New Mexico through Del Rio, TX, in January; expanding from Nogales, AZ, through Laredo, TX, in January; adding central California in February only; and then moving eastward to encompass New Mexico through McAllen, TX, in March.

5.4 Turbulence Impacts

The Aerostar manufacturer guidance on weather limitations states that flight in severe bumpiness is prohibited, and input from local operators equates this impact to the more formal category of severe turbulence (5). The AFCCC modeled turbulence output is available for the categories of greater than or equal to 1 (light through extreme), 2 (moderate through extreme), or 3 (severe through extreme). The probabilities of experiencing these levels of turbulence are broken up into three levels: low (1,000–6,000 ft above ground level (AGL)), mid (6,000–10,000 ft AGL), and high (10,000–50,000 ft AGL).

The following discussion will focus primarily on the occurrence of severe or greater turbulence at the low and mid levels. Checks of the occurrence of moderate through extreme turbulence indicate that it can generally be expected to add 5–10% to the frequency given for severe through extreme turbulence. A short summary of the turbulence by month at the highest level 10,000–50,000 ft AGL is provided at the end of this section.

The frequency of severe or extreme turbulence at the low level is consistently highest during the overnight hours and lowest during the afternoon for all the months of the year. Similar to the results found in upper air wind impacts, this is not what might be expected based on thermal turbulence caused by afternoon heating. One possible explanation for this result is that turbulence in ACMES might be primarily associated with a low-level jet (6). Figure 8 shows a typical pattern for maximum turbulence during a winter month.

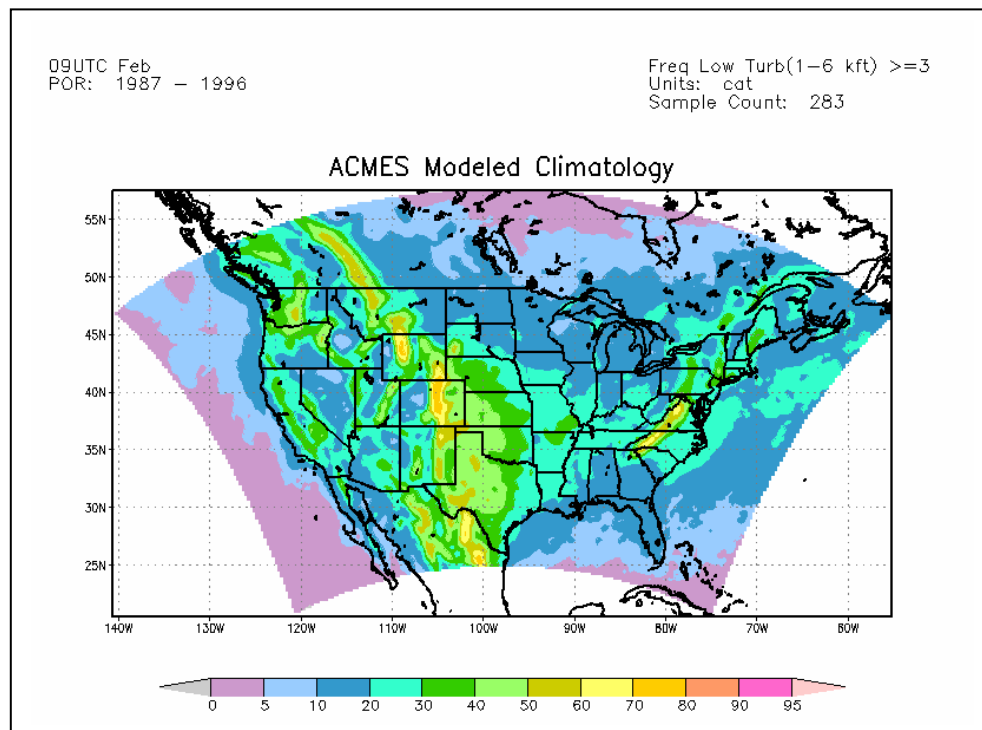


Figure 8. A sample chart of severe or extreme turbulence frequency percentages at 1,000–6,000 ft AGL, for February at 0900 Zulu (09Z).

The frequency of turbulence at the lowest height level varies significantly over the time of day, time of year, and region. The minimum value generally occurs at approximately 2200 Zulu (22Z) (2 p.m. PST/4 p.m. CST) increasing to a maximum frequency around 1000 Zulu (10Z) (2 a.m. PST/4 a.m. CST). Figure 9 shows the range of times by month experiencing the minimum and maximum turbulence values for most of the U.S./Mexico border region at the 1,000–6,000 ft AGL level. Autumn months experience turbulence less frequently than the rest of the year. As depicted in figure 8, the most turbulence is usually found over central California, western New Mexico, and west Texas. An area east of Big Bend, TX, often shows the highest concentration in all seasons except the summer, when the area of maximum turbulence tends to shift westward incorporating Nogales, AZ, and Marfa, TX, as well as central California. The ACMES model indicates turbulence at the middle level 6,000–10,000 ft AGL is significantly less frequent than at the lower level, reaching a maximum of 20% over the Big Bend and surrounding areas in the spring and summer. Diurnal variations are also much less evident in

this middle level, although the spring and summer months do show an increase during the overnight hours from the lowest turbulence frequencies in the afternoon hours as seen year round in the lower level.

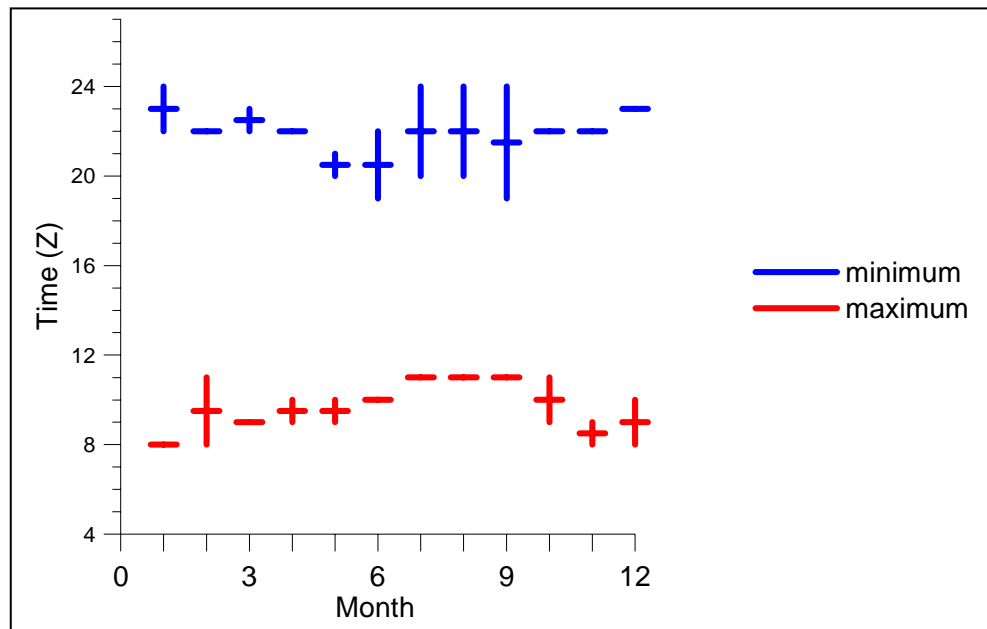


Figure 9. Time ranges of minimum and maximum severe or extreme turbulence frequencies at 1,000–6,000 ft AGL by month, with month 1 starting with January.

NOTE: A horizontal line indicates a single time or the median of a range of times.

Details on low- and middle-level severe or extreme turbulence frequencies are provided below:

- During the winter months, the minimum daytime turbulence of at least severe intensity below 6,000 ft AGL occurs 5–20% of the time, with less frequent turbulence over western Arizona and more frequent up to 30% east of Big Bend, TX. These percentages increase overnight to a maximum of predominantly 20–40%, although eastern California and western Arizona are more commonly 10–20%, while central California and the New Mexico bootheel may reach up to 50% and the Big Bend region up to 60%.
- The wintertime middle level severe or extreme turbulence is generally less than 5%, but up to 10% over the highest elevations in central California, New Mexico, and west Texas.
- During the spring, severe turbulence occurs less than 5% of the time at the minimum mid-afternoon time everywhere except 5–10% for both the Pacific and Gulf coasts as well as the Big Bend area. As in the winter months, the highest frequencies in the spring typically reach 20–40%. However, the coastal regions are more likely to fall in the lower end of that range, and central Arizona is more commonly 10–20%. Central California reaches a maximum of 50% and the Big Bend region up to 70%.

- The springtime middle level severe or extreme turbulence is less than 5% everywhere around 2100 Zulu (21Z), except exhibiting the winter pattern up to 10% over the coasts and the Big Bend area in March. The frequencies remain under 5% overnight for California and Arizona, but increase to 5–10% for much of New Mexico and Texas and 10–20% between Marfa and Del Rio, TX.
- During the summer months, the period of minimal severe turbulence less than 5% of the time at the low level stretches to 5 h or more during the afternoon. Maximum frequencies during the night vary somewhat between June through August, with the maximum turbulence decreasing somewhat from June to August and the maximum regions becoming central California, Nogales, AZ, and Marfa, TX, rather than east of Big Bend, TX. In June and July, most of New Mexico and west Texas experience severe or greater turbulence at least 30–50% of the time, although the Texas region from McAllen to Brownsville is much lower at 5–10%; the Pacific coast, Arizona, and Laredo, TX, are at 10–30%; and Marfa, TX, and central California are up to 50–70%. The maximum value in these ranges is generally 10% lower in August.
- The summertime middle level severe or extreme turbulence is always less than 5% except 5–10% during the night over Nogales, AZ, and higher elevations in New Mexico; and 10–20% over the Texas region from Big Bend to Del Rio.
- During the fall months, the U.S./Mexico border region experiences severe or extreme turbulence at the low level less than 5% of the time at 22Z in September and October, with the frequency increasing up to 20% for many areas in November. The maximum frequencies occurring at night are predominantly 10–30%, reaching up to 40% over central California and Nogales, AZ; 30–50% from Marfa to Big Bend, TX; and 40–60% east of Big Bend, TX.
- The fall-time middle level severe or extreme turbulence is always less than 5% except 5–10% east of Big Bend, TX, overnight in September; and over central California, central New Mexico, and east of Big Bend, TX, overnight in November.

The existence of severe or extreme turbulence at the highest level 10,000–50,000 ft AGL does not vary diurnally. The ACMES climatology shows this level of turbulence occurring less than 5% of the time over the entire U.S./Mexico border region from June through October. Texas and areas of higher elevation in central California and New Mexico are most likely to exceed 5% during the rest of the year. The maximum frequency is still only up to 20% associated with the Big Bend area during December through March.

5.5 Icing Impacts

Icing on various parts of the Aerostar UAS may degrade its performance, and icing in the fuel filter may cause the engine to cut out. Actual icing observations are limited, and the ACMES model expects icing to occur less than 5% of the time throughout the border region for all the

individual hours of each month, at each of the three height levels equivalent to those described in section 5.4. However, since icing may have a significant impact on UAS flights, it is worthwhile to look at the frequency of occurrence of conditions favorable to create icing. The AFCCC Web site also provides this capability through its Climo Atlases, and an example output is shown in figure 10.

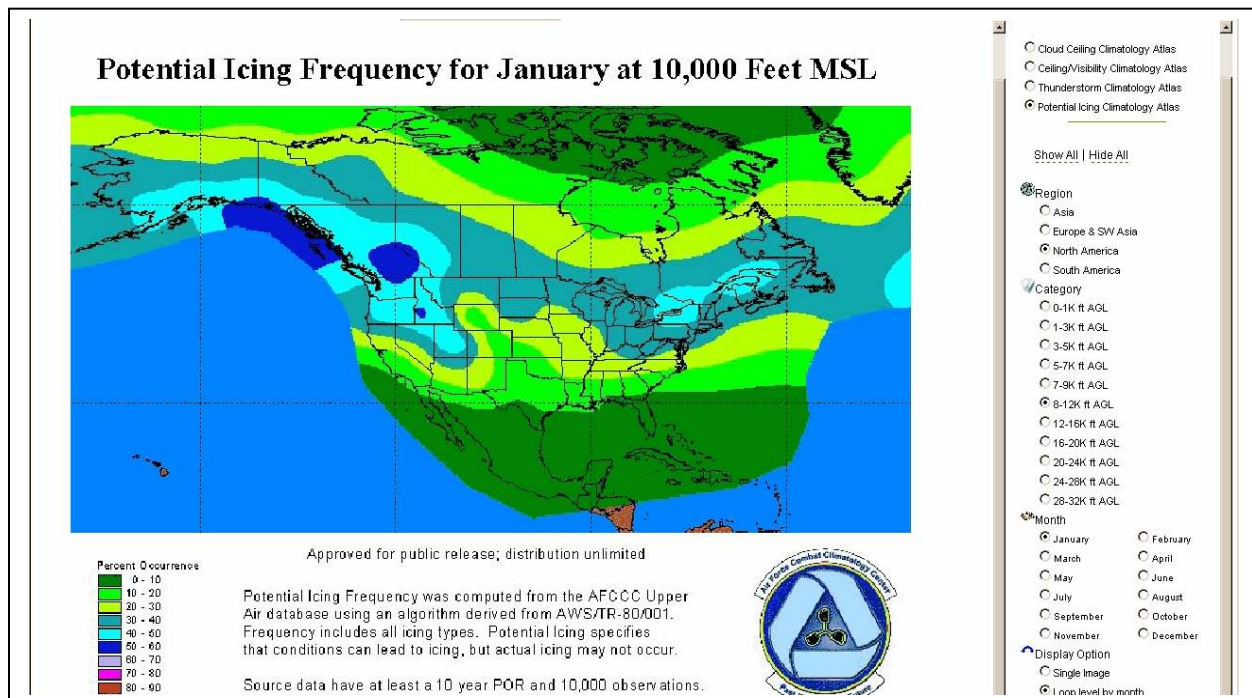


Figure 10. Sample plot of the frequency of conditions favorable for icing, for January at 10,000 ft MSL.

These monthly plots are not broken down by individual times of day. Although the height level choices are labeled as a range AGL, the plot headings appear as a single value at 1000, 2000, 4000, 6000, and 8000 ft AGL, then 10000, 14000, and 18000 MSL. Higher levels are ignored as being above the flight limit of the Aerostar. Conditions are favorable for potential icing 0–10% of the time for much of the area for many months, but increasing to 10–20% of the time during the winter and spring months at mid levels for some regions, and for more extensive regions for much of the year above 10,000 ft MSL. At 18,000 ft MSL, the highest frequencies actually occur during the summer months based on moisture availability, reaching 20–40% over Arizona through west Texas. Areas experiencing favorable conditions for icing more than 10% of the time are summarized below.

- The California border region experiences favorable conditions for icing 10–20% of the time from January and February from 8,000 to 18,000 ft. The eastern portion of California also has this frequency of favorable conditions at 8,000 to 10,000 ft in December and at 6,000 ft in January and February. In March, favorable conditions 10–20% of the time can be expected from 6,000 to 10,000 ft over western California and

6,000 to 18,000 ft over central and eastern California. Outside these winter and early spring periods, the only other months California experiences these conditions is during July and August at the 18,000 ft level.

- Arizona has favorable conditions for icing 10–20% of the time from 6,000 to 18,000 ft during January through March. This is also true for central and eastern Arizona during December, when favorable conditions over western Arizona are limited to 8,000 to 10,000 ft. In April through June, favorable conditions 10–20% of the time are primarily limited to the 18,000 ft level over the eastern half of the state. In July and August, the western side of the state also has favorable conditions 20–30% of the time while the majority of the state experiences them 30–40% of the time, but only at the highest 18,000 ft level. September and October return to the 10–20% frequency at 18,000 ft, although the 14,000 ft level is also favorable for icing over the eastern half of the state in October.
- New Mexico experiences conditions favorable for icing similar to those listed for eastern Arizona, except New Mexico is more likely to have favorable conditions at 14,000 ft as well as 18,000 ft in the spring and fall. In addition, the higher likelihood at 18,000 ft persists beyond the summer months, falling only to 20–30% in September.
- Over west Texas from El Paso through Big Bend, conditions are favorable for icing 10–20% of the time from 6,000 to 18,000 ft during December through February, although favorable conditions are somewhat less likely at the lower levels east of El Paso, which also has favorable conditions at 4,000 ft in January. El Paso also has favorable conditions at 8,000 to 18,000 ft in March, October, and November, with these conditions becoming less likely at the lower levels moving eastward. The remaining months April through September all show favorable conditions more than 10% of the time only at the 18,000 ft level, reaching 30–40% of the time over the El Paso area and 20–30% over Marfa and Big Bend in July and August.
- For the rest of the Texas border region, favorable conditions for icing are primarily limited to 10–20% of the time at the 18,000 ft level in every month except November, although the central region from Del Rio to Laredo also experiences these favorable conditions at 14,000 ft in December through February.

5.6 Visibility Impacts

The published guidance to Aerostar operators highlights the potential danger to the UAS platform when landing in low visibility conditions. This guidance, as included in the appendix, provides instructions if the operator is not able to see the UAS when it has descended to 1,000 ft AGL. Local operators consider the visibility threshold to be three statute miles for both take off and landing (5). The climatological frequency of having visibility along a slant path up to 1,000 ft AGL is not available. ACMES provides surface visibility in conjunction with low cloud

ceilings, so it's not possible to distinguish the percentage of time that the visibility is below 3 mi. However, looking at the frequency of experiencing either a cloud ceiling below 3,000 ft AGL or visibility below 3 mi will provide at least a maximum value that visibilities less than 3 mi occur.

The percentage of time these low cloud ceilings or low visibilities occur is typically highest along the Gulf coast, gradually becoming lower moving westward along the border region, becoming less than 5% most of the time over western Arizona and eastern California. Another maximum occurs along the Pacific coast, with a sharp decline to the east of San Diego, CA. An example of this pattern is shown in figure 11. This pattern over Texas varies somewhat during the spring and summer months, when the coastal region experiences less frequent low ceiling or low visibility conditions than the area between Del Rio and McAllen.

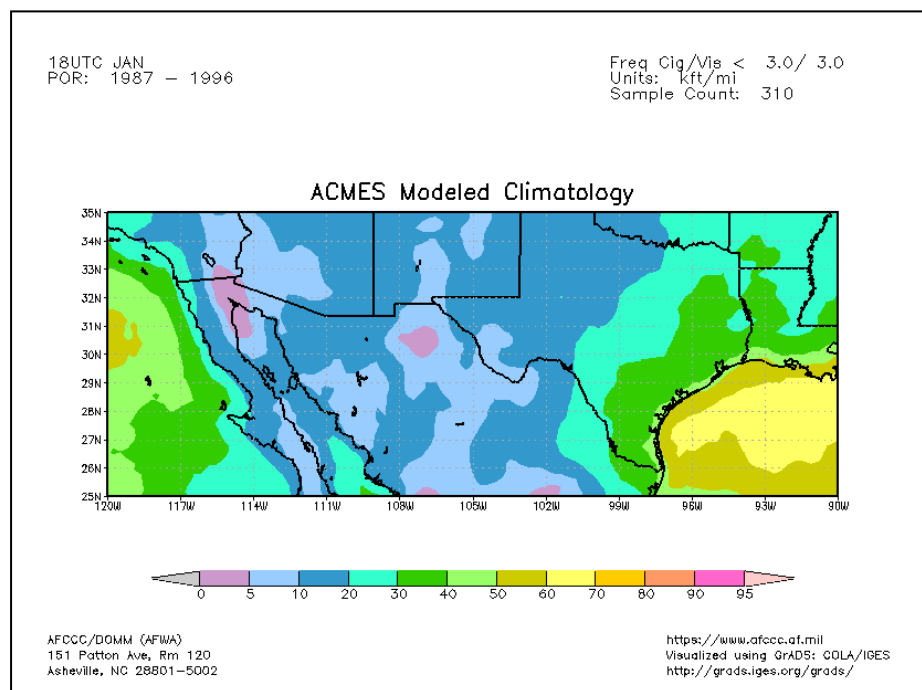


Figure 11. A common midday climatology pattern showing the frequency of either cloud ceiling below 3,000 ft or visibility less than 3 mi, valid 18Z for January.

In addition to significant variations between locations, the frequency of low cloud ceilings or low visibilities varies substantially by the time of day and the season. Maximum frequencies are consistently seen during the early morning hours, with minimums during the afternoon. The majority of the border region experiences low clouds or low visibilities most often during the winter months and least often during the summer months, although the San Diego area exhibits its maximum during the morning hours in June and July. Some specific values for the percentage of time cloud ceilings are below 3,000 ft AGL or visibilities are below 3 mi are highlighted:

- The San Diego area in California reaches a maximum frequency of 50–60% between 4 and 9 a.m. in June and July, decreasing to 30–50% in the spring and fall and 10–30% in the winter morning hours. The afternoon frequencies are typically 20–30%, but somewhat higher in July and lower in the spring and fall.
- The vicinity of Yuma, AZ, is least likely to have low cloud or low visibility conditions, which occur less than 5% of the time at any particular time except potentially up to 10% during the morning hours in January.
- The stretch along the U.S./Mexico border between central Arizona and the Big Bend region in Texas generally has low cloud ceilings or low visibilities 5–20% of the time during the morning and less than 5% of the time in the afternoon. Western New Mexico and eastern Arizona are most likely to experience the high end of that range during the morning hours in the winter months, with a maximum frequency up to 30% in December. Even the morning hours remain below 5% for all of the New Mexico and Arizona border regions during the summer months.
- Del Rio, TX, is most likely to experience cloud ceilings below 3,000 ft AGL or visibilities below 3 mi 30–50% of the time during the early morning hours, decreasing to less than 5% of the time during the afternoon hours, except 5–20% in November through January.
- The Texas border from the area surrounding Laredo to McAllen reaches 40–60% frequencies of low cloud or low visibility conditions in the mornings from September through May, with the higher values more often seen in the vicinity of McAllen. These conditions become less frequent in the summer mornings, reaching a minimum of 10–30% in July. The most common afternoon frequencies are 10–20% around Laredo and 20–40% near McAllen in the winter, and less than 5% the rest of the year.
- The Gulf of Mexico coastal region near Brownsville, TX, produces the highest occurrences of cloud ceilings below 3,000 ft or visibilities below 3 mi, with a maximum value of 60–80% in the early morning hours in December. The lowest morning frequencies of 10–30% are seen in July; with 20–40% seen in May, June, August, and September; and 50–70% in January through March as well as in October and November. The afternoon frequencies are generally 20–30% during the winter except somewhat higher in December, 5–20% in the spring and fall, and 5–10% in June and August with a minimum of less than 5% in July.

5.7 Fog Impacts

The presence of fog may hinder the operation of the Aerostar UAS through its association with icing potential in cold temperatures, as well as through the impact of reduced visibility as addressed in section 5.6.

Since fog leads to low visibility, it is not surprising that the occurrence of fog is closely associated with the patterns of low visibility or low cloud ceilings. The highest frequencies of fog up to 50% or more of the time are seen during the morning hours along the Pacific coast in the late spring through the summer and predominantly during the winter but extending through the spring and fall along the Atlantic coast. Fog conditions occur less frequently but still a noticeable amount over the Texas border region east of Big Bend as well as over the central Arizona border region. Fog is moderately infrequent over eastern California, western Arizona, and central New Mexico eastward to Big Bend, TX. Fog may persist into the afternoon hours 5–30% of the time along the San Diego coast, while the rest of the border region experiences fog in the afternoon less than 5% of the time. Nighttime fog is primarily restricted to generally 30% of the time over western California and 20% of the time over eastern Texas, as well as 10% of the time in the central Texas and central Arizona border regions. Additional details on the existence of fog over the U.S./Mexico border region are provided below:

- Western California is most likely to experience fog in May and June, reaching 30–50% of the time overnight and in the early morning hours. The San Diego coastal area continues to experience this frequency of fog in July and August, when the frequency further inland at those times drops to 10–30%. Fog may persist during the summertime midday to evening hours up to 30% of the time over the coast, but becomes less than 5% of the time further inland for those times of day in every season. The frequency of fog over western California during the late night and early morning drops to 10–30% in November through January and 20–40% for the remainder of the year.
- With a few exceptions, any probability of fog greater than 5% for a specific time and month over the Arizona border region is predominantly restricted to the central area around Nogales. That area experiences fog 5–20% of the time during the nighttime and morning hours in December through February, decreasing to 5–10% in March. Any fog in the summer is much more likely to be only around the early morning hours. Fog occurring 5–10% of the time further west and east in Arizona is only expected during the night and morning hours in December and January.
- The ACMES fog climatology shows a small local maximum of 5–20% over the Nogales area in Arizona, which frequently includes the New Mexico bootheel in the winter months, while this area moves east to produce a 5–10% probability of fog over the bootheel area in the morning hours in August through November. The rest of the New Mexico and El Paso border areas only show fog 5–10% of the time during the morning hours in December and January.

- The stretch of the Texas border from Marfa through the Big Bend region is most likely to experience fog during the morning in December, with a maximum probability of 10–30%. The probability decreases to 5–20% in January and February, but remains 5–10% around 6–7 a.m. for the entire rest of the year. The only nighttime fog over 5% for this region is over the Big Bend area after midnight up to 10% of the time in December.
- During the winter months between 5 and 9 a.m., the likelihood of fog along the Texas border diminishes with distance from the Gulf of Mexico, as shown in figure 12(a). Probabilities reach 30–40% around Laredo and 20–30% around Del Rio. Nighttime probabilities for both areas in December through February are generally 5–10%, with afternoon probabilities less than 5%. In April through September fog over this region is primarily restricted to 10–30% of the time for a short period close to 6 a.m., with lower probabilities of 5–10% during July and August. During the summer months, the ACMES pattern of fog probabilities changes to portray higher values between Big Bend and Del Rio than seen over the area surrounding Laredo, as shown in figure 12(b). October and November include a 5–10% probability of fog after midnight increasing to a maximum of 30–50% around Laredo and 10–30% near Del Rio in the early morning and decreasing to less than 5% in the afternoon and evening hours.

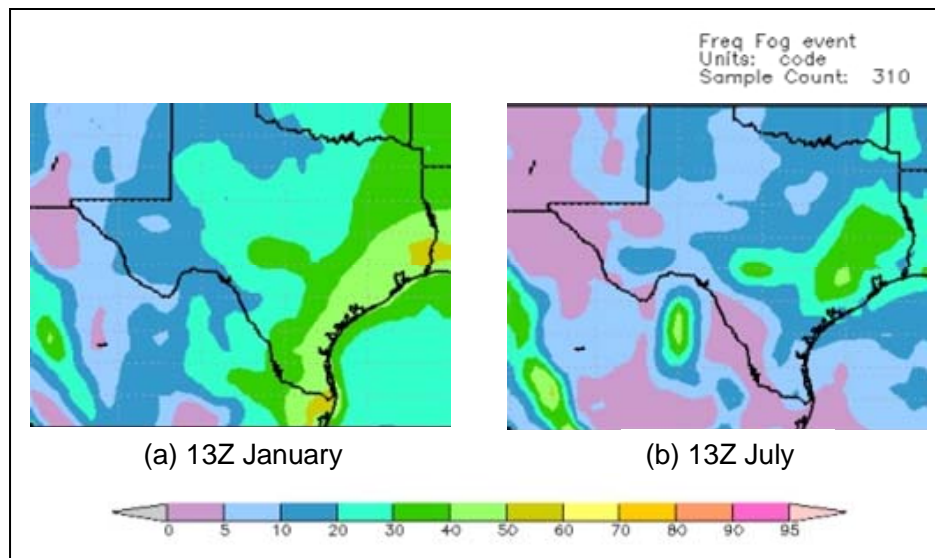


Figure 12. A comparison of early morning fog probability patterns over the Texas border region for (a) winter and (b) summer months.

- The probability of fog from December through February over McAllen, TX, is typically 5–20% in the late evening, increasing overnight to a maximum of 40–50% in the early morning, and then falling off to 5–10% by noon and less than 5% through the afternoon. October and November are similar to the winter months except the nighttime fog is likely to form later and somewhat less frequently. In March through June, probabilities greater

than 5% may occur between midnight and 9 a.m., with a maximum probability of 30–40% around 6 a.m. Although July through September experience probabilities below 5% almost all the time, they may reach 10–30% around 6 a.m. and 5–20% around 7–8 a.m.

- Fog occurs more than 5% of the time over the Gulf coast around Brownsville, TX, from November through February for all times of the day and night except noon to 5 p.m. It is most likely in December, with probabilities of at least 20–30% for all those times and reaching 40–60% from 6–8 a.m. November, January, and February match those morning maximum probabilities, but are somewhat less likely to experience fog at the other times. For March through June as well as October, probabilities are primarily 5–20% overnight, reaching a maximum of 30–50% in the early morning, and dropping quickly to less than 5% by 10 a.m. July and August show the lowest probability of fog of 10–30% at 6–7 a.m. and less than 5% all the other times. In September, Brownsville, TX, experiences fog 5–10% of the time overnight, 20–40% of the time 6–7 a.m., and 5–20% around 8 a.m.

5.8 Rain Impacts

5.8.1 Any Precipitation

As with fog, precipitation may be associated with adverse impacts on the Aerostar based on icing potential and low visibility. The ACMES model parameter choices include hourly probabilities of any precipitation and monthly probabilities of precipitation greater than one-hundredth of an inch in a day. Since these are surface parameters and the border region experiences little snowfall, the following discussion will refer to these probabilities as rain, but these events may also be tied to frozen precipitation or icing potential particularly at higher elevations.

The greatest probability of receiving more than one-hundredth of an inch of rain in a day is 10–30% over western California in January through March. This probability decreases to 5–20% in April and May and October through December. Nowhere along the U.S./Mexico border is likely to receive more than one-hundredth of an inch of rain in a day more than 5% of the time in the summer and early fall, except for the San Diego area, which may record that amount up to 20% of the time in June and September and up to 10% of the time in July and August. The Gulf coast near Brownsville, TX, is most likely to experience at least one-hundredth of an inch of rain in a day in December, with probabilities up to 20%. The entire Texas border region east of Big Bend as well as the central Arizona border region may receive one-hundredth of an inch of rain in a day up to 10% of the time in November through March.

The time of day also affects the probability of rain, with the highest probabilities in the late evening hours for western California. The other regions that experience rain more than 5% of the time are overnight for central Arizona during the winter months, and either late afternoon in the winter or early morning in winter and spring for eastern Texas. Additional details are provided below:

- Western California has the greatest potential for rain during the late evening through late morning hours. Along the coast near San Diego, probabilities generally remain above 5% for all hours in January through March as well as June, becoming less than 5% during the mid-morning through mid-afternoon hours in other months. Figure 13 shows the pattern of the probability of rain over the San Diego area by time of day and month. The areas within the dashed lines are times when these probabilities extend inland from the coast, while the other times represent the coastal area only with the remainder of western California having probabilities of rain of less than 5% at those times.

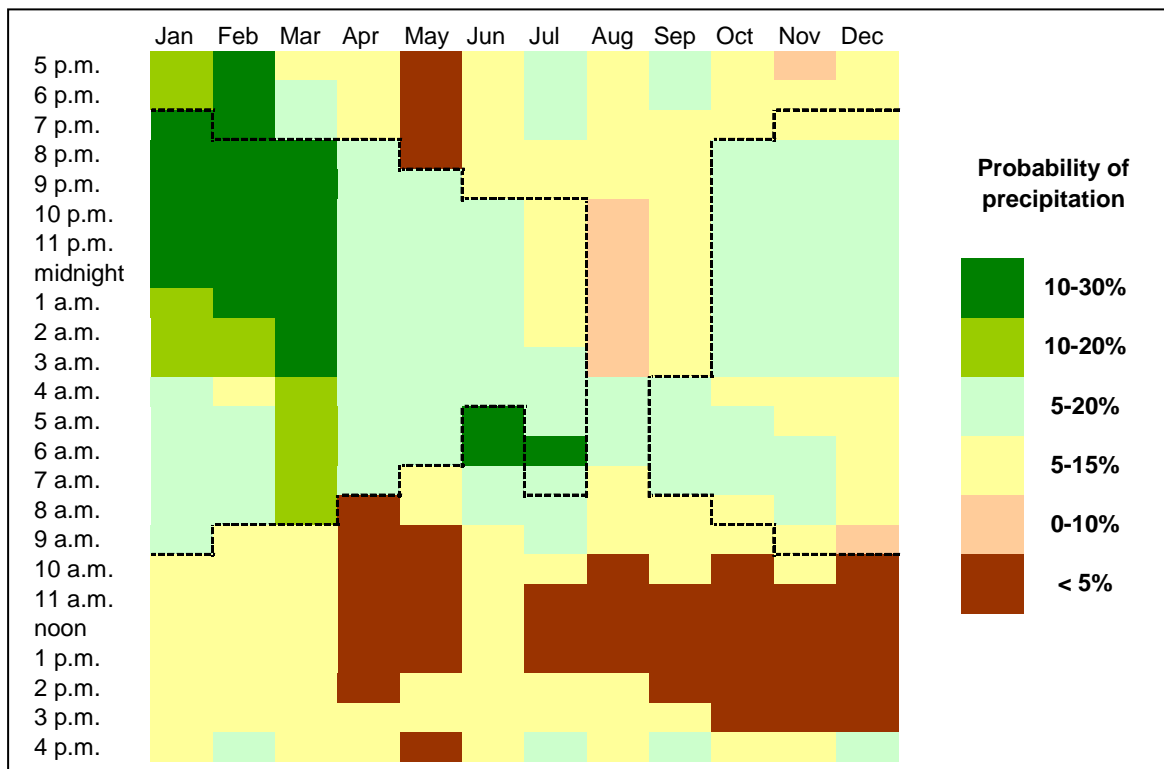


Figure 13. Probabilities of any precipitation for San Diego, CA, by time of day and month.

NOTE: The probabilities within the dashed lines are valid inland into western California, with the other probabilities above 5% are limited to the coastal region.

- The area around Nogales, AZ, has rain up to 10% of the time between midnight and 8 a.m. during the months of December through February.

- The maximum probability of rain for the border region surrounding Del Rio, TX, is up to 20% between 6 and 9 a.m. during November through February. This region experiences rain up to 10% of the time around 6–7 a.m. in October and March through June, as well as between midnight and 6 a.m. in November and December.
- The section of the border region from Laredo to McAllen, TX, experiences similar rain probabilities up to 20% as seen around Del Rio during the early morning hours in the winter. However, as shown in the summer fog pattern (figure 12b), these areas are not affected by the moisture reaching Del Rio from areas to the east in March through June. McAllen may still have rain up to 10% of the time at 6–7 a.m. in March and April.
- The Gulf coast around Brownsville, TX, has two daily maxima for rain probabilities in November through February. The evening maximum between 6 and 9 p.m. is up to 10% except up to 20% in December. The morning maximum is somewhat higher, reaching up to 30% in December and January and up to 20% in November, February, and March around 6 a.m. Values up to 20% persist until 8 a.m. in December through February, with values up to 10% for another hour or two past the highest probabilities in November through March as well as around 6–7 a.m. in April.

5.8.2 Thunderstorms

Any problem the Aerostar might have based on rain, such as low visibility, potential icing, and turbulence, would be as bad or worse in the vicinity of thunderstorms. The Aerostar Weather Limitations document (see the appendix) prohibits flight in the vicinity of cumulonimbus clouds.

The AFCCC thunderstorm frequency Climo Atlas portrays much smaller percentages than seen in the ACMES thunderstorm event frequencies. An example of the differences is shown in figure 14, where the upper plot based on the Climo Atlas only has probabilities greater than 10% over southeastern Arizona and the New Mexico bootheel, while the lower plot for a comparable time shows probabilities greater than 10% in the majority of the region from central Arizona eastward through McAllen, TX. The Climo Atlas is based on observations of thunderstorms, with interpolated data between observation sites. Although this will likely underestimate thunderstorms over mountainous terrain, the Climo Atlas data appear reasonable for the actual occurrence of a thunderstorm over the majority of points in the U.S./Mexico border region. The ACMES thunderstorm frequency plots probably reflect the modeled conditions where thunderstorm activity is possible, which is also valuable information to have. Therefore, the following paragraph discussing the probability of thunderstorms is based on the Climo Atlas plots available every 3 h by month, and the subsequent paragraph based on the ACMES plots refers to the probability of thunderstorm conditions available every hour by month.

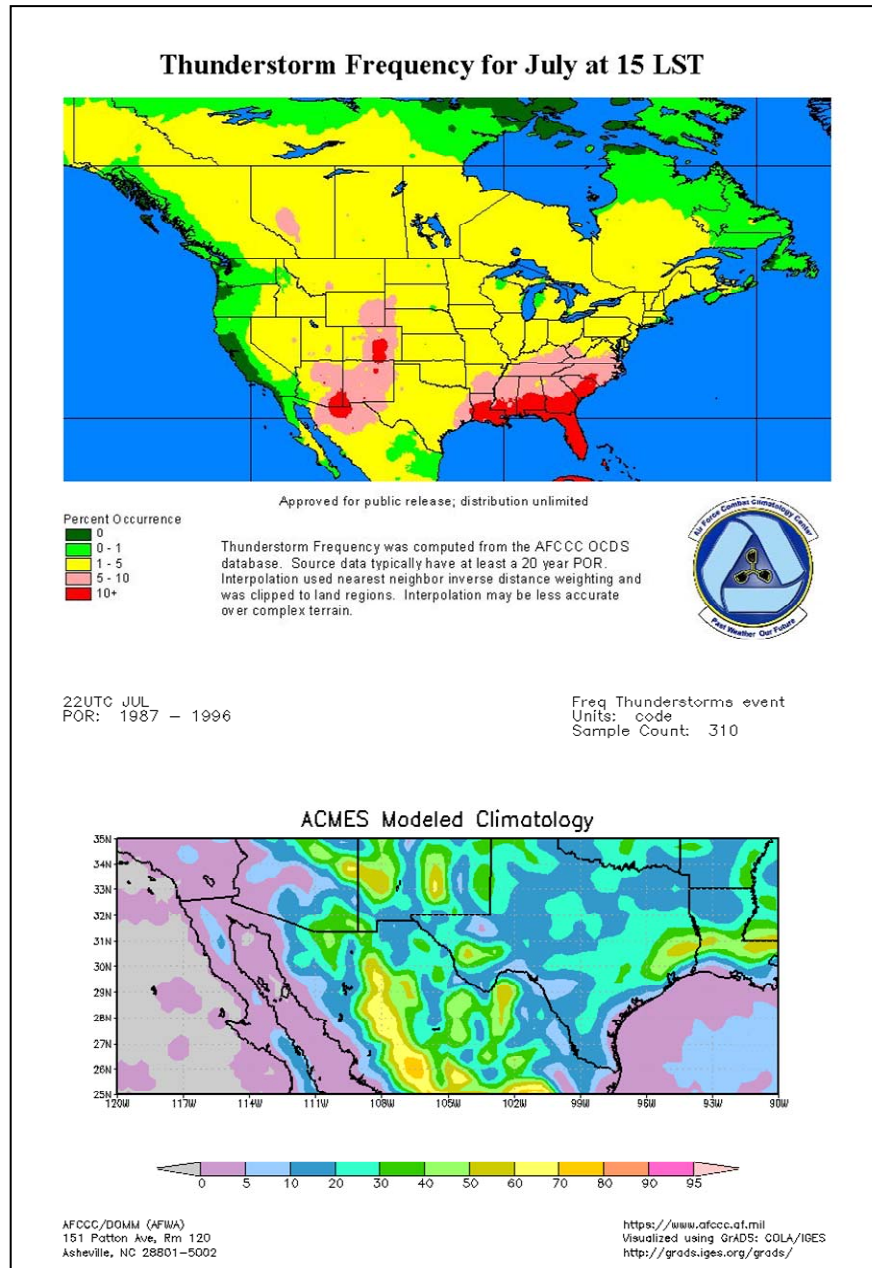


Figure 14. Thunderstorm probability plots for comparable times based on the Climo Atlas (top) and the ACMES model output (bottom).

NOTE: The text refers to the results of the Climo Atlas as thunderstorm probabilities, and the ACMES plots as thunderstorm condition probabilities.

The probability of a thunderstorm occurring at a specific time and location only exceeds 5% from central Arizona eastward to Marfa, TX, during the afternoon hours in July and August, extending into the evening over central Arizona through the New Mexico bootheel in those

months, as well as over eastern Arizona in the afternoon in September. The maximum values over 10% are only seen over eastern Arizona and the New Mexico bootheel during the afternoon hours in July and August.

The probability of thunderstorm conditions over the U.S./Mexico border region is never more than 10% at any particular time in November through April. From central Arizona eastward probabilities are frequently up to 20% during the afternoon and evening hours in May through September, and extending into October for the Texas border regions east of Big Bend. These probabilities up to 20% also persist throughout the day other than the very early morning hours in July and August from central Arizona through Del Rio, TX, when the afternoon and early evening probabilities reach 20–40%. The Texas regions east of Del Rio to McAllen are less likely to experience thunderstorm conditions overnight, but also reach 20–40% during the afternoon and early evening hours. The Gulf coast shows thunderstorm condition probabilities of 10–30% from 6 a.m. to 6 p.m. from June through October. In addition to the typical afternoon and evening maximum probabilities, there is frequently a lesser but noticeable increase in thunderstorm condition probabilities after sunrise in the summer months. A particular region may experience a wide range of values, especially areas with widely varying terrain where mountain peaks may have much higher values than the surrounding lower elevations. Additional details are provided below:

- The California border region hardly ever experiences thunderstorm conditions more than 5% of the time. The coastal area around San Diego has slightly higher thunderstorm condition probabilities up to 10% during the day and evening in February and the afternoon hours in March. The remainder of the California border region might experience thunderstorm condition probabilities up to 10% in the early morning or afternoon hours in August or September.
- Western Arizona also rarely exceeds thunderstorm condition probabilities of 5%. Exceptions up to 10% include the early evening hours in February and March, early morning in July, and overnight in September. August is the most likely month for thunderstorm conditions around Yuma, with probabilities up to 10% throughout the day and up to 20% in the early morning hours.
- Central and eastern Arizona show significantly higher probabilities of thunderstorm conditions. November is the only month when probabilities never exceed 5%. December through April may reach 10% during the afternoon and evening hours. May, June, and October are also primarily limited to afternoon and evening thunderstorm conditions, but with a higher probability up to 20%. The chance of thunderstorm conditions goes up significantly in July through September. Between midnight and 3 a.m. the probabilities are the lowest at no more than 10%, but these probabilities rise up to 20% most of the rest of

the time, and 20–40% during the afternoon and early evening hours. Somewhat higher values are possible over the mountains. The highest probabilities occur from 1 to 6 p.m. in August.

- Thunderstorm condition probabilities for the New Mexico border region are below 5% in November through April. The summertime thunderstorm condition probabilities are similar to those described for eastern Arizona, particularly over the bootheel region with slightly lower probabilities over the central New Mexico border area.
- The El Paso area in Texas also has thunderstorm condition probabilities below 5% from October through April. May and June increase to up to 20% between mid-afternoon and midnight. September also has values up to 20% from mid-afternoon through early evening, but is less likely to experience thunderstorm conditions overnight and slightly more likely to have thunderstorm conditions during the morning. As seen in eastern Arizona and New Mexico, July and August are the predominant months for thunderstorm conditions over far west Texas, with probabilities up to at least 10% for every hour of the day, reaching a maximum of 20–40% during the afternoon and evening hours.
- Thunderstorm conditions are not as concentrated in the summer months farther east in Texas. The Big Bend area has thunderstorm condition probabilities up to 10% during the evening hours in the winter, expanding to the afternoon and night in March and April. Thunderstorm conditions up to 10% in October are most likely during the evening or morning hours, and are always below 5% in November. May through September have likelihoods above 5% almost every hour, with a maximum up to 30% during the evening hours in June through August.
- Around Del Rio, TX, thunderstorm condition probabilities are below 5% during the winter, increasing up to 10% during the evening hours in March, October, and November, and up to 10% most of the time in April. May through September show probabilities at least up to 10% all the time, reaching a maximum up to 30% during the evening hours as well as the early morning in August and September.
- Laredo and McAllen, TX, experience the maximum probability of thunderstorm conditions up to 30–40% or higher at 6–8 p.m. in May through September. Laredo shows probabilities up to 10% at those times in February and March, when probabilities remain below 5% over McAllen. Probabilities up to 20% in the afternoon and evening in April expand to the morning hours and later in the evening in May through September, then decrease to no more than 10% in October, and no more than 5% overnight in October.
- The Gulf coast around Brownsville, TX, has thunderstorm condition probabilities below 5% all the time in December through April, as well as between 11 p.m. and 5 a.m. in every month other than September. The other times may reach up to 10–30%, with the highest probabilities during the afternoon hours in June through September.

6. Conclusions

Many weather conditions have been documented as having a potential adverse impact on the operation of the Aerostar UAS, including some temperatures, clouds, wind, turbulence, icing, visibility, fog, and rain. Each of these parameters is much more likely to occur at specific months and times of day than at others. These tendencies are also highly dependent on the particular location. This report documents many details on the estimated probability of each individual parameter exceeding the threshold value expected to affect the Aerostar for the areas in the United States along its border with Mexico. This information should be helpful in planning where and when a UAS would be most likely to be effective.

Rather than manually analyzing climatology plots or reading through lengthy reports, a UAS operator would benefit significantly from an automated decision aid with the ability to ingest climatology data in order to plan appropriate locations and times for specific requirements. This study has shown that sufficient climatology data are available to run such a decision aid over the CONUS. AFCCC also has extensive climatology data available for many other areas of the world. ARL is developing a UAS routing decision aid for near-term operational decisions that considers weather impacts on a UAS based on a weather forecast. This decision aid could be expanded to provide longer-term intelligence for planning UAS operations based on climatology.

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Appendix

Weather Limitations

1. Weather Conditions

a. State 1:

- 1) Ambient temperature 10–30 °C or
- 2) Ambient temperature 1–10 °C, relative humidity under 70%
- 3) No immediate threat to UAV

b. State 2:

- 1) Ambient temperature 1–10 °C, relative humidity over 70% (possible fog, clouds, rain)
- 2) Expect carburetor icing
- 3) Operate engine according to flight in icing conditions

c. State 3:

- 1) Ambient temperature under 1 °C, relative humidity under 70%
- 2) Possible formation/accumulation of icing in the fuel filter
- 3) Inform landing site manager. Filter replacement required before flight
- 4) Inform daily manager before flying in this condition

d. State 4:

- 1) Ambient temperature under 1 °C, and relative humidity over 70% (possible fog, clouds, rain)
- 2) Expect icing on various UAV parts
- 3) Expect carburetor icing
- 4) Expect pitot pipe icing
- 5) Expect ice accumulation in fuel filter

e. **Flight in state 4 conditions is prohibited, unless authorized by daily manager.**

f. **Flight in clouds/visible humidity is restricted to a maximal altitude of 1,000 ft below freezing level.**

2. Clouds

- a. **Flight in clouds should be avoided.**
- b. **Warning: Flight in the vicinity of CB clouds is severely prohibited for fear of wind gusts and severe bumpiness.**

3. Wind

- a. **Takeoff/landing during the day**
 - 1) Nose – 25 kts
 - 2) Side – 15 kts
 - 3) Tail – 2 kts
- b. **Takeoff/landing during the night or trainee EP**
 - 1) Nose – 20 kts
 - 2) Side – 10 kts
 - 3) Tail – 2 kts
 - 4) Cruising altitude – 40 kts

4. Bumpiness

- a. **Flight in severe bumpiness is prohibited.**
 - 1) IAS – ± 3 kts difference between IAS command and report
 - 2) ALT – ± 150 ft difference between command and report (throttle opens/closes frequently or to abnormal values)

5. Landing Site Environment Temperature

- a. **Training – maximum of 30 °C/heat wave**
- b. **Operational – maximum 33 °C, pending authorization of daily manager**
- c. **Above 33 °C – prohibited, unless authorized by flight line manager**

6. Fuel Temperature for Ignition

- a. **30 °C – to be measured no more than 5 min prior to ignition**

Weather Emergency Procedures

Flight in State 2 Conditions

7. Diagnosis

- a. Ambient temperature – between 1–10 °C
- b. Relative humidity – over 70%
- c. Possibility of fog, clouds and rain

8. Implications

- a. Fear of carburetor icing

9. Actions

- a. Recommended RPM – over 5,000
- b. CHT – KEEP over 120°

Flight in State 3 Conditions/Flight Above Freeze Altitude

10. Diagnosis

- a. Ambient temperature – under 1 °C
- b. Relative humidity – under 70%

11. Implications

- a. Fear of fuel filter icing

12. Actions

- a. ADD the following to your regular flight routine:
 - 1) Icing checks – payload, landing gear, arresting hook, steering
 - 2) Scanning for clouds
- b. RPM:
 - 1) Recommended RPM – over 5,000
 - 2) Every 20 min – gradually OPEN and CLOSE throttle
- c. CHT – KEEP over 120°

Flight in State 4/Icing Conditions

13. Diagnosis

- a. **Ambient temperature – under 1 °C**
- b. **Relative humidity – over 70%**
- c. **Possible icing on the UAV**
- d. **IAS/ALT loop problems (UAV behavior peculiar)**
- e. **Possibility of fog, clouds, and rain**

14. Implications

- a. **Possible icing in various UAV parts (during icing, UAV performance declines)**
- b. **Possible icing in carburetor or pitot pipe**
- c. **Possible icing in fuel filter, may cause engine cut**

15. Actions

- a. **RPM – KEEP over 5,000**
- b. **Every 10 minutes – gradually OPEN and CLOSE throttle**
- c. **CHT – KEEP over 120°**
- d. **CHECK every 3 min (UTILIZE payload operator):**
 - 1) **Icing check – payload, landing gear, arresting hook, steering**
 - 2) **Scan for clouds**
- e. **PAY ATTENTION for ALT loop malfunctions.**
- f. **If deliberately crossing clouds while in state 4:**
 - 1) **Crossing – as a last resort**
 - 2) **IAS stick, throttle – INTEGRATE (leave HDG in KNOBS)**
 - 3) **RPM – KEEP over 5,500**
 - 4) **CHT – KEEP over 130°**
 - 5) **KEEP 10–15 kts over designated IAS**
 - 6) **When performing turns, DO NOT EXCEED ROLL 15°**
 - 7) **LEAVE icing conditions ASAP**

8) RPM, IAS, ALT – CHECK frequently, VERIFY compatible

- In the event of UAV icing, thawing will occur only under freezing altitude.
- Be watchful for landing site weather conditions.

Crossing Clouds

16. Diagnosis

- a. Clouds in flight route

17. Implications

- a. Fear of icing, bumpiness
- b. While inside a cloud:
 - 1) No payload visibility

18. Actions

- a. If flying in state 4 conditions, SWITCH to “Flight in State 4/Icing Conditions” emergency procedure.
- b. ATTEMPT to evade clouds, UTILIZE payload
- c. CHECK freezing level, cloud data – type, base, top, coverage
- d. IAS – according to IAS table +5 kts
- e. UAV/Station transmitters – ON, HIGH
- f. Tracking – VERIFY OK
- g. UAV data – VERIFY OK
- h. If experiencing irregular phenomenon:
 - 1) Evade cloud by:
 - a) Descending
 - b) Climbing
 - c) 180° turn
- i. CONSIDER switching to “Flight in state 4/icing conditions”

- 1) Flying near or inside CB clouds is strictly prohibited.
- 2) It is prohibited to fly inside a cloud or visible humidity, unless at least 1,000 ft under freezing level.
- 3) It is prohibited to fly in state 4 conditions.

Joining Landing Site in Low Visibility Conditions

19. Diagnosis

- a. **Severe weather conditions:**
 - 1) Formation of bad weather conditions in the mission area
 - 2) Forecasting data
 - 3) Landing site reports

20. Implications

- a. **Inability to perform mission**
- b. **Danger of damage to UAV**
- c. **Difficulty in recognition and establishing eye contact**
- d. **In the case of landing site cloud/fog coverage – difficulty in landing the UAV**
- e. **Fear of severe bumpiness**
- f. **Fear of icing (SEE “Flight in State 4/Icing Conditions” emergency procedure)**

21. Actions

- a. **CHECK detailed weather forecast:**
 - 1) Clouds
 - 2) Visibility
 - 3) Entrance/Exit times
- b. **RPM, IAS, ALT – CHECK frequently, VERIFY compatible**
- c. **UAV/Station transmitters – ON, HIGH**
- d. **RH – CONSIDER updating**
- e. **UTILIZE payload picture**
- f. **Fuel limit for CTR – 5 liters above regular limit**
- g. **IAS – CONSIDER accelerating according to fuel quantity/bumpiness**
- h. **If flying in rain – AVOID flight above inhabited areas**
- i. **Navigation lights, Strobe – ON**
- j. **Before arrival at CTR:**

- 1) SILENCE sources of noise before entering CTR, UTILIZE all free personnel in establishing eye contact
- k. **Upon arrival at CTR – KEEP secure altitude, when the weather improves – DESCEND for landing**
- l. **In case of landing in low visibility:**
 - 1) 19 in. – SWITCH to optimal scale
 - 2) Low alt warning – CALIBRATE
 - 3) UPDATE EP – azimuth, range, altitude
 - 4) In conditions for bumpiness and wind shear:
 - a) During circuit – IAS – 10 kts over IAS table
 - b) During Final – IAS – 5 kts over IAS table
 - 5) Altitude – DESCEND to 1,000 ft above landing site
 - 6) If eye contact not established at 1,000 ft – PERFORM descent from station:
 - a) Regular procedures – PREPARE
 - b) BRIEF crew
 - c) Flight mode – KNOBS
 - d) PERFORM wide circuit, UTILIZE GPS location and heading and F.L. altitude
 - e) PERFORM a 100–200 ft descent at the end of every circuit, attempting each time to establish eye contact
 - f) Upon establishing steady eye contact:
 - i. RELINQUISH control to EP for landing
 - ii. SWITCH to regular procedures
 - g) Minimal altitude for descent – 300 ft
 - h) Out of eye contact – GO AROUND (climb to 600 ft)
- m. **Fuel quantity under 3 liters:**
 - 1) Descent limit – 150 ft, JUDGE for under-shoot
 - 2) CONSIDER landing site obstacles
 - 3) CONTINUE landing attempts until 1.5 liters
 - 4) Under 1 liter of fuel – PLAN ground impact in an inhabited area

Acronyms

00Z	0000 Zulu
10Z	1000 Zulu
12Z	1200 Zulu
18Z	1800 Zulu
21Z	2100 Zulu
22Z	2200 Zulu
ACMES	Advanced Climate Modeling and Environmental Simulations
AFCCC	U.S. Air Force Combat Climatology Center
AGL	above ground level
ALT	altimeter
ARL	U.S. Army Research Laboratory
CB	cumulonimbus
CHT	Cylinder Head Temperature
Climo	Climatological
CONUS	Continental U.S.
CST	Central Standard Time
CTR	Control Zone or Area
EP	External Pilot
F.L.	Flight Level
GPS	Global Positioning System
HDG	heading
IAS	Indicated Air Speed
MSL	mean sea level
PST	Pacific Standard Time

RH	Return Home
RPM	revolutions per minute
RTNEPH	Real-Time Cloud Nephanalysis
TAAC	Technical Analysis and Applications Center
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
Z	Zulu or Greenwich Mean Time

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